

DRAFT

TOTAL MAXIMUM DAILY LOAD (TMDL)

For

Dissolved Oxygen

In Savannah Harbor
Savannah River Basin

Chatham and Effingham Counties, Georgia

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Savannah Harbor Dissolved Oxygen TMDL Executive Summary

This report establishes a Total Maximum Daily Load (TMDL) for dissolved oxygen (DO) for the Savannah Harbor from Fort Pulaski (River Mile 0) to the Seaboard Coastline Railway Bridge (River Mile 27.4). The Savannah Harbor is located at the mouth of the Savannah River where it discharges to the Atlantic Ocean. The Savannah River, including the Harbor, serves as the boundary between Georgia and South Carolina.

The Environmental Protection Agency Region 4 (EPA R4) is establishing this TMDL to satisfy a consent decree obligation established in Sierra Club v. EPA, Civil Action No: 94-CV-2501-MHS (N.D.GA). The Consent Decree requires TMDLs to be developed for all waters on Georgia's most current Section 303(d) list consistent with the schedule established by Georgia for its rotating basin management approach. By August 30, 2004, TMDLs are to be established for all waters in the Savannah and Ogeechee River Basins. The State of Georgia and EPA agreed that EPA would be responsible for developing this TMDL.

In the absence of the consent decree obligation, EPA would not have chosen to propose this TMDL at this time due to concerns surrounding the existing site-specific DO criterion for the Harbor. The protective water quality criterion is a fundamental component of a meaningful TMDL since the criterion establishes the target upon which the TMDL is based. In this case, the applicable DO site-specific criterion for the Harbor established by the State "are minimum instantaneous and will apply throughout the water column. The dissolved oxygen criteria is no less than 3.0 mg/l in June, July, August, September, and October; no less than 3.5 mg/l in May and November; and no less than 4.0 mg/l in December, January, February, March, and April." EPA disapproved the criterion in 1989 as not protective of the coastal fishing aquatic life use of the Harbor. The criterion is under-protective of aquatic species in the upper part of the water column and over-protective of aquatic species in the lower part of the water column. To achieve a concentration of 3 mg/l of DO in the lower part of the water column, all sources of oxygen-demanding wastes must be removed and DO must be injected into the Harbor. This is not a realistic nor desired scenario (see the discussion of natural conditions in Section 3); however, until the criterion is revised, the TMDL establishes a 100% reduction of oxygen-demanding substances from all NPDES-regulated discharges in the watershed (from the Thurmond Dam near Augusta, Georgia to the Savannah Harbor) in order to attain the existing, applicable site-specific criterion.

Data collection and studies have been underway since 1989 to determine the appropriate site-specific DO criterion for the Harbor. The recent culmination of these efforts into hydrodynamic and water quality modeling has resulted in a recommendation by EPA for a revised site-specific criterion for DO. EPA's recommended criterion is: One-day water column averages of 2.3 mg/l DO; Seven-day water column average of 3.0 mg/l DO; and Thirty-day water column average 3.55 mg/l DO (see Section 3). Because of the consent decree obligation, it is necessary for EPA to propose this TMDL before the criterion

could be revised. A TMDL to attain the recommended criterion is 362,000 lbs/day of Total Ultimate Biochemical Oxygen Demand and would require an approximate 30% reduction in the total load of oxygen-demanding substances currently being directly discharged to the Harbor or to the upstream watershed from Thurmond Dam downstream (as measured during the summer of 1999) by NPDES-regulated sources. This alternative TMDL is presented in the Report to provide information to stakeholders regarding the possible outcome of a revised TMDL if the site-specific criterion is revised as recommended by EPA.

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1. Introduction

TMDLs are required for impaired waters on a State's Section 303(d) list as required by Section 303(d) of the Federal Clean Water Act and implementing regulation 40 CFR 130. A TMDL establishes the maximum amount of a pollutant a waterbody can assimilate without exceeding the applicable water quality standard. The TMDL then allocates the total allowable load to individual sources or categories of sources through wasteload allocations (WLAs) for facilities regulated by the National Pollutant Discharge Elimination System (NPDES) program, and through load allocations (LAs) for all other sources. In the TMDL, the WLAs and LAs provide a basis for states to reduce pollution that will lead to the attainment of water quality standards and protection of the designated use.

The TMDL for the Savannah Harbor in the Savannah River Basin satisfies a consent decree obligation established in Sierra Club v. EPA, Civil Action No: 94-CV-2501-MHS (N.D.GA). The consent decree requires TMDLs to be developed for all waters on Georgia's most current Section 303(d) list consistent with the schedule established by Georgia for its rotating basin management approach. By August 30, 2004, TMDLs are to be established for all impaired waters in the Savannah and Ogeechee River basins

2. Watershed Characterization

The Savannah River Basin is located on the border of eastern Georgia and western South Carolina and has a drainage area of 10,577 square miles. The portion of the Savannah River Basin impacted by this TMDL is the middle and lower watersheds encompassing the area from Thurmond Dam to the Atlantic Ocean. Land uses within these watersheds are mostly forestlands, wetlands and agriculture.

The area of concern for this TMDL is the Savannah Harbor located at the mouth of the Savannah River where the Savannah River discharges to the Atlantic Ocean. The Savannah River serves as the boundary between Georgia and South Carolina, and the Harbor is also shared by both states. The Savannah Harbor from Fort Pulaski (Mile 0) to Seaboard Coastline R/R Bridge (River Mile 27.4) is the segment identified on the State of Georgia's Section 303 d list as impaired for dissolved oxygen. The hydrodynamic and water quality model used to develop the TMDL extends upstream on the Savannah River to River Mile 61.0 near Clyo, Georgia at USGS station 02198500. The downstream end of the model extends approximately 19 miles offshore from Oyster Island to cover the navigational channel of Savannah Harbor. The modeling study covers the Savannah River, the Front River, the Middle River, the Little Back River, the Back River, the South Channel, and the offshore portions in the Atlantic Ocean. Figure 1 is a map that shows the model's extent and overall location of the study area.

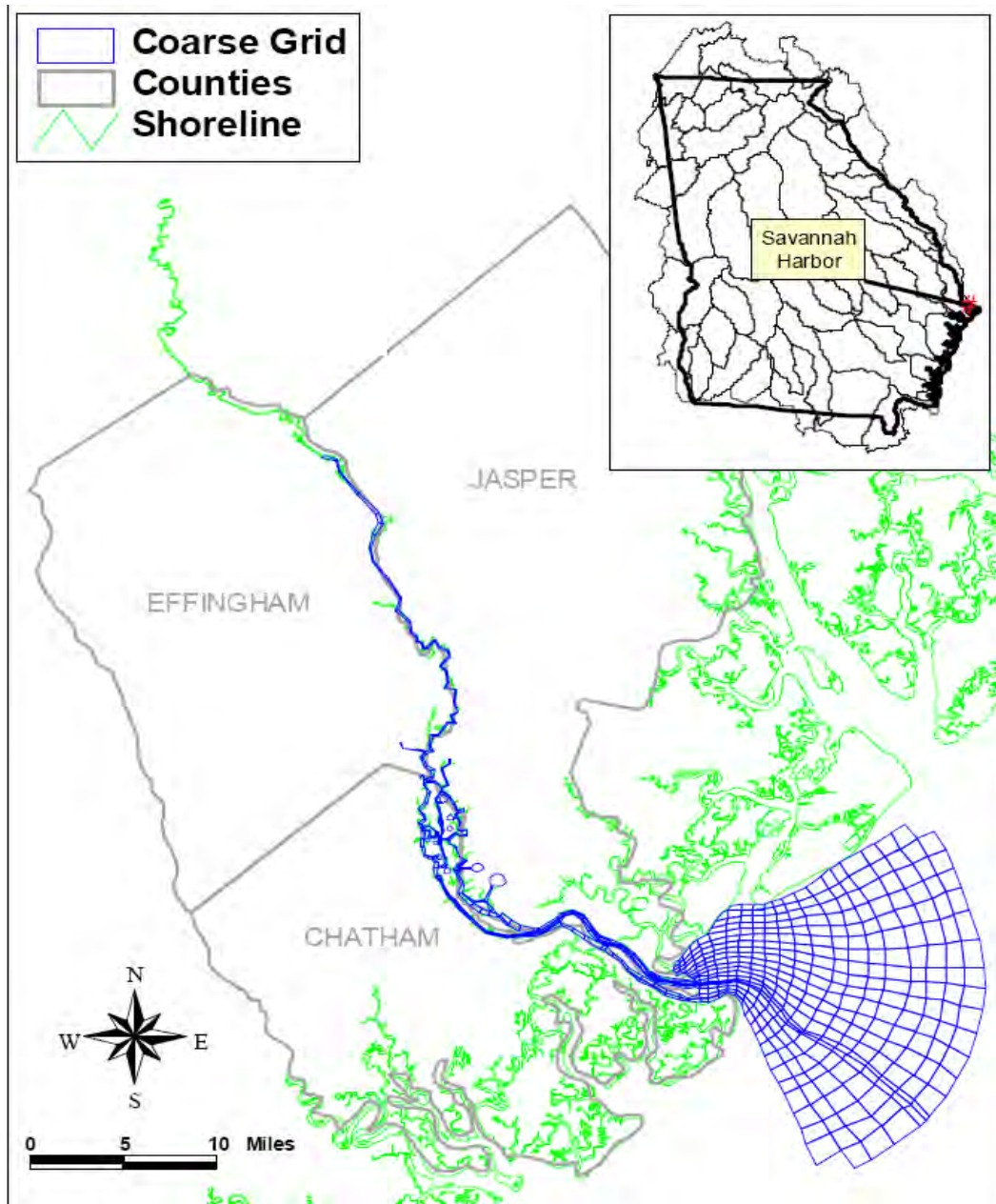


Figure 1 Savannah Harbor Location Map

The Savannah Harbor from Fort Pulaski (River Mile 0) to Seaboard Coastline R/R Bridge (River Mile 27.4) was listed on Georgia's 2002 Section 303d list for failing to meet the dissolved oxygen (DO) criterion associated with the State of Georgia's Coastal Fishing water quality use designation based on data collected in the summers of 1997 and 1999.

Summaries of the field studies conducted over the past ten years used to develop the TMDL, can be found in Appendix A. The purpose of the field studies was to characterize the dissolved oxygen (DO) regime of the harbor, to determine the appropriate causes of

impairment, and to provide sufficient data and information to develop a complex water quality model. The data used in the calibration and confirmation of the hydrodynamic and water quality models were collected by the Georgia Ports Authority (GPA), the U.S. Geological Survey (USGS), the Georgia Environmental Protection Division (GaEPD), the U.S. Army Corps of Engineers (USACE), and the USEPA. An extensive amount of data analysis was performed by the GPA through their contractor, Applied Technology and Management, Inc. (ATM, 2000). Additional details on the hydrodynamic modeling can be found in Appendix B.

3. Target Identification

3.1 Current Water Quality Standard for Dissolved Oxygen

The existing water use classification for the Savannah River from Fort Pulaski (River Mile 0) to Seaboard Coastline R/R Bridge (River Mile 27.4) is coastal fishing. The coastal fishing classification is established in Georgia's Rules and Regulations for Water Quality Control Chapter 391-3-6-.03(6)(c)(iv)(f). In 1989, a site-specific dissolved oxygen (DO) criterion was established by GaEPD for this section of the Savannah River. This site-specific criterion is "are minimum instantaneous and will apply throughout the water column. The dissolved oxygen criteria is no less than 3.0 mg/l in June, July, August, September, and October; no less than 3.5 mg/l in May and November; and no less than 4.0 mg/l in December, January, February, March, and April."

States are required under the CWA to submit newly-adopted or revised water quality standards to EPA for review and are either approved or disapproved. In 1989, GaEPD submitted the site-specific criterion for the Savannah Harbor to EPA Region 4 (EPA R4). Upon review, EPA R4 disapproved this site-specific criterion for CWA purposes as not protective of the coastal fishing designated use. The instantaneous minimum of 3 mg/l (the criterion that applies during the critical summertime conditions) is not protective of aquatic life in the upper part of the water column and has now been shown to be over-protective of aquatic life in the lower parts of the water column. However, until such time that a replacement criterion is adopted, the existing criterion (even though it is disapproved) remains in effect. Since CWA regulations require TMDLs to be established to attain the applicable water quality criterion, the instantaneous minimum DO of "no less than 3.0 mg/l in June, July, August, September, and October" is the numeric target for calculation of the TMDL.

3.2 Recommended DO Criteria for Savannah Harbor

Over the past fifteen years, EPA R4, GaEPD and the South Carolina Department of Heath and Environmental Control (SCDHEC), as well as various other entities have been collecting data, developing tools and performing studies to determine the appropriate site-specific DO criterion for the Savannah Harbor. (See Appendix A, Summary of Studies.) The culmination of these efforts has recently allowed EPA to develop a recommendation for an appropriate criterion for protection of aquatic life in the Harbor. EPA's recommendation for a marine DO criterion for the Harbor can be expressed as follows:

One-day water column average DO = 2.3 mg/l
Seven-day water column average DO = 3.0 mg/l
Thirty-day water column average DO = 3.55 mg/l

A discussion and other information on the basis for this recommendation may be found in Appendix C. The recommended criterion combines the features of traditional water quality criteria with a new biological framework, one that integrates exposure to low DO over time rather than averaging DO exposure conditions into one single value. The two primary documents that EPA R4 used in determining the recommended DO criteria are: (1) Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras, November 2000, EPA-822-R-00-012 (EPA 2000), and (2) National Saltwater Criteria for Dissolved Oxygen: Potential Addenda to Virginian Providence Saltwater Criteria for Warmer and Colder Waters, October 2003. (Thursby/EPA-ORD 2003).

The Virginian Providence Saltwater Criteria, which serves as the basis for EPA's criteria recommendation for the Savannah Harbor, recommends a 30-day water column average of 4.8 as protective of aquatic life. Water quality modeling of the Savannah Harbor indicates that the 30-day average DO of the Savannah Harbor under natural conditions in the critical segment was 3.95 mg/l due to the physical configuration of Savannah Harbor (see Section 4.2) and the high water temperatures experienced in the water column during the summer (greater than 30 degrees C for 30 or longer). GaEPD defines natural conditions as "those that would remain after removal of man-made or man-induced sources of pollution, but may include irretrievable effects of man's activities, unless otherwise stated. Natural conditions shall be developed by an examination of historic data, comparisons to reference watersheds, application of mathematical models, or any other procedure deemed appropriate by the Director." By policy, GaEPD has established that a 10% reduction below the natural condition is protective of the aquatic life use. Applying this policy to EPA's recommendation for a site-specific criterion for the Harbor, a recommended 30-day water column average for protection of the aquatic life use is 3.55 mg/l (instead of the Virginia Providence criterion of 4.8 mg/l).

Modeling also predicted the natural conditions of the Harbor expressed as a 1-day water column average and a 7-day water column average. The 1-day water column "natural condition" is 3.5 mg/l and the 7-day water column "natural condition" is 3.6 mg/l. The Virginian Province criterion documentation demonstrates that aquatic species are protected at a 1-day water column average of 2.3 mg/l and a 7-day water column average of 3.0 mg/l. EPA's recommended criteria for the Savannah Harbor adopts the Virginian Province criterion for the 1 day and 7 day water column averages.

4. Modeling Approach

EPA R4 and its contractor, Tetra Tech, Inc. (Tetra Tech), have developed a calibrated hydrodynamic and water quality model for the Savannah Harbor System. The models

were calibrated to data collected from the year 1997 to the present. These models were used to determine the appropriate DO TMDL for Savannah Harbor.

4.1 Hydrodynamic Model for Savannah Harbor

Tetra Tech was contracted by the EPA Region 4 to support the development of a TMDL for dissolved oxygen in the Savannah Harbor Estuary. To support the development of the TMDL, Tetra Tech was tasked to setup a hydrodynamic model that met the following criteria:

- Capturing the key hydrodynamic processes of transport in the estuary,
- Using a model that is public domain and whose code has been peer reviewed on other TMDLs,
- Linking the hydrodynamic model to a water quality model,
- Delivering the model to the federal agencies involved in the TMDL process and,
- Running the model for multiple hydrologic periods to examine point and nonpoint sources.

In January 2004, the United States Army Corps of Engineers (USACE), Savannah District contracted with Tetra Tech to provide a hydrodynamic modeling report and deliver the report in March 2004. The model code, modeling results, in both time series and statistical formats, and a database (containing model comparison data) are all readily available for peer review and are provided with the report, “Development of the EFDC Hydrodynamic Model for the Savannah Harbor, March 2004.”

Tetra Tech and EPA R4 have updated the original March 2004 model (2004 Tetra Tech) to address legitimate comments and concerns provided by reviewers, including improvement of channel configuration and direct inclusion of temperature impacts from Savannah Electric power plants thermal discharges and City of Savannah storm water flows. A brief model description and as well as a description of the improvements are contained in Appendix B.

This hydrodynamic model provides the needed transport mechanisms and a technically defensible basis for the subsequent development of the Savannah Harbor water quality model.

4.2 Water Quality Model for Savannah Harbor

EPA R4 has developed a DO water quality model for Savannah Harbor. This DO model addresses the impacts of both natural and man-made oxygen demanding loadings to the harbor, impacts of upstream flows and ocean tides along with the Harbor’s physical configuration.

The draft EPA Region 4 Savannah Harbor Model Report (August 2004) provides the modeling details.

5. Source Assessment

A TMDL evaluation examines the known potential sources of the pollutant in the watershed, including facilities regulated by the National Pollutant Discharge Elimination System (NPDES) program, other sources of pollution, and background levels.

5.1 Point Sources Discharging Oxygen Demanding Substances

Discharge from municipal and industrial facilities may contribute oxygen-demanding substances to receiving waters as ultimate carbonaceous biochemical oxygen demanding (CBODu) substances and ammonia. Total Ultimate BOD (TBODu) equals the sum of CBODu and the multiplication of ammonia times a conversion factor of 4.57.

The cumulative oxygen-demanding substance load for facilities authorized by NPDES permits to discharge into the Harbor, expressed as TBODu, is 367,000 lbs/day. Of this authorized 367,000 lbs/day, facilities were cumulatively discharging 99,000 lbs/day of TBODu in the summer of 1999. This is known as their “existing” load; the load authorized by NPDES permit (i.e., the 367,000 lbs/day) is known as the “permitted” load.

Table 1 Savannah Harbor Permit Loads

Facility name	NPDES	Current Permit Limits and Calculated Loads						
		Flow	BOD5	BOD5	NH3	NH3	F_ratio	TBODu
Georgia		mgd	mg/l	lbs/day	mg/l	lbs/day		lbs/day
Hardeville	SC0034584	1.0	30.0	253		85	2.0	894
Fort James	GA0046973	0.8		10850		22	5.0	54350
Weyerhaeuser	GA0002798	0.1	0.0	6700			4.5	30150
Garden City	GA0031038	2.0	30.0	1125	17.4	290	2.4	4026
Whilshire	GA0020443	4.5	30.0	1126	17.4	653	2.5	5799
Travis Field	GA0020447	1.5	20.0	250	11.6	145	2.3	1239
President Street	GA0025348	27.0	18.5	4166	12.9	2905	3.9	29522
International Paper	GA0001998	1.3		25000			10.7	269328
Englehard	GA0048330					400		1828
Kerr McGee*	GA0003646	0.6						

* Kerr McGee has an iron oxygen-demanding load to the system which exerts 44,000 lbs/day of immediate oxygen demand.

Table 2 Savannah Harbor 1999 Summer Oxygen Demanding Loads

Facility name	NPDES	Oxygen Demanding Load - Summer 1999				TBODu
		Flow	BOD5	NH3	F_ratio	
Georgia		mgd	lbs/day	lbs/day		lbs/day
Hardeville	SC0034584	0.5	12.6	0	2.0	25
Fort James	GA0046973	19.3	762	22	5.0	3911
Smurfit	GA0002798	2.6	180	2	4.5	819
Garden City	GA0031038	1.1	51	0	2.4	122
Whilshire	GA0020443	3.1	295	117	2.5	1272
Travis Field	GA0020447	0.8	56	0	2.3	129
President Street	GA0025348	18.8	1128	93	3.9	4824
International Paper	GA0001998	30	8100	125	10.7	87241
Englehard	GA0048330	1	0	66		302
Kerr McGee*	GA0003646	13				

* Kerr McGee has an iron oxygen-demanding load to the system that exerts 44,000 lbs/day of immediate oxygen demand.

Oxygen-demanding loads from City of Savannah municipal storm water, and heat loads from the three Savannah Electric power facilities were evaluated in the model and shown to have no measurable impact on the DO levels in the critical areas of concern.

Loadings of oxygen-demanding substances from sources upstream of the Harbor, below Thurmond Dam, also impact the Harbor DO levels. The majority of these dischargers are in the Augusta, Georgia area. The total loading of oxygen-demanding substances for the upstream sources authorized by NPDES permit is 358,000 lbs/day TBODu. The total loading of existing oxygen-demanding substances discharged in the summer of 1999 was 135,000 lbs/day. Appendix D provides the NPDES permitted loadings for the major upstream dischargers.

The loads from these discharges impact the Harbor and are taken into account in the Savannah Harbor TMDL. The transport of the oxygen-demanding substances through the river system is calculated using the Savannah River EPD-RIV1 model. Approximately 75% or 100,000 lbs/day of the oxygen-demanding substances discharged around Augusta reach the upstream portion of the Harbor according to EPA's modeling. Figure x illustrates the Savannah River segments covered by the EPD-RIV1 model and the segment covered by the Savannah Harbor Model.

5.2 Background Sources and Nonpoint Sources

The vast majority of the non-NPDES loadings of oxygen-demanding substances are from natural background sources including detritus transported in the stream, detritus from marsh areas flowing directly into the Harbor, and tidally- transported detritus from the ocean. See Appendix C for a description of the marsh loads and the MACTEC report on the concentration of oxygen-demanding substance in the ocean boundary waters. Table 3 provides an estimate of the various background loadings to the system.

Table 3 Natural Background Oxygen Demanding Substance Loads in TBODu

	Oxygen Demanding Substance Loads, TBODu
Marsh	150,000 lbs/day
Upstream	85,000 lbs/day
Ocean	CBODu = 6mg/l; Ammonia = 0.1 mg/l

6 Dissolved Oxygen TMDL for Savannah Harbor

A TMDL establishes the total pollutant load that a waterbody can assimilate and still achieve the applicable water quality standard. The components of a TMDL include a wasteload allocation (WLA) for facilities and sources regulated by the NPDES program, a load allocation (LA) for all other sources (including natural background), and a margin of safety (MOS) to either implicitly or explicitly to account for uncertainty in the analysis. Conceptually, a TMDL is defined by the equation:

$$\text{TMDL} = \Sigma \text{WLA} + \Sigma \text{LA} + \text{MOS}$$

The TMDL for the Savannah Harbor in the Savannah River Basin is in terms of oxygen-demanding substances expressed as TBODu, where:

- $\text{TBODu} = \text{CBODu} + \text{NBODu}$
 - $\text{CBODu} = \text{BOD5}$ multiplied times a f-ratio
 - $\text{NBODu} = \text{ammonia}$ multiplied times 4.57 conversion factor

6.1 Critical Conditions

Critical conditions are established in Georgia's *Rules and Regulations for Water Quality Control* Chapter 391-3-6 as the "collection of conditions for a particular waterbody used to develop Total Maximum Daily Loads (TMDLs), determine NPDES permit limits, or assess the protection of water quality standards. The Division considers appropriate

critical conditions to represent the event that would occur once in ten years on the average or less often, unless otherwise stated.”

In May 2000 and May 2003 letters, Georgia and South Carolina set the critical conditions for Savannah Harbor as:

- Upstream boundary determined by the States’ Savannah River Model
- Harbor model kinetic rates and parameters as determined by the Savannah Harbor Model calibration
- 1999 harbor channel bathymetric physical conditions
- the critical flow as equivalent to the seven-day ten year low flow (7Q10), taking into account the low flow release from Thurmond Dam
- Meteorological and tidal conditions based on 1999 data
- Dischargers at NPDES limits expressed as monthly averages

For an estuarine TMDL, critical conditions are more complex than the critical conditions typically considered for a river system (e.g., summer temperatures and the 7Q10 flow). Tidal dynamics play an important role in the DO levels of the Savannah Harbor. Therefore, critical conditions applied to the Savannah Harbor DO TMDL are based on model runs in August of 1999 incorporating the existing harbor physical conditions and the upstream 7Q10 low flow as well as actual historic tidal regimes, temperature and other meteorological conditions measured during these periods. Heat loads from the electrical facilities were also considered in the TMDL.

The critical segment of the Savannah Harbor system is defined as the segment of the Harbor with the lowest daily DO average. This segment is a four mile segment around the Savannah Harbor sediment basin (River Mile 9.3 to 14.3). Appendix F illustrates the various critical conditions.

6.2 TMDL Numeric Target

By CWA regulations, TMDLs are established to attain the applicable water quality standard for the waterbody. This existing, applicable criterion is the end-point or target to which the TMDL is established. For the critical condition in the Savannah Harbor (i.e., summertime conditions), the existing, applicable numeric criterion for DO is an instantaneous minimum of not less than 3.0 mg/l in June, July, August, September, and October. This TMDL is established to achieve this criterion throughout the water column during critical conditions.

Based on the TMDL modeling, the existing criterion is unattainable under any conditions (including natural conditions in the Harbor) without an artificial injection of DO. The injection of DO into a large estuary system is not considered a realistic nor desirable scenario. This outcome of the TMDL (i.e., the need for an addition of DO) is due to the inappropriateness of the site-specific criterion of 3 mg/l to the deepest parts of the Harbor. Under natural conditions, the deeper parts of the Harbor minimum DO

concentration is less than 3 mg/l. EPA is recommending a revised site-specific marine DO criterion as follows:

- One-day water column average DO = 2.3 mg/l
- Seven-day water column average DO = 3.0 mg/l
- Thirty-day water column average DO = 3.55 mg/l or an allowable DO deficit of 0.4 mg/l.

An alternate TMDL is being presented in this document to achieve EPA's recommended site-specific criterion. However, this alternate TMDL can be applied only if the current numeric criterion is revised, by regulation, a TMDL must be established to attain the applicable water quality criterion.

6.2 Wasteload Allocation (WLA)

The wasteload allocation is the portion of the total load that is provided to the NPDES facilities. This TMDL provides the WLA as oxygen-demanding substances, expressed as TBODu in lbs/day. The WLA is meant to protect aquatic species in the Harbor. The TMDL is expressed as a "gross" allocation to all NPDES sources in the Harbor and in the Savannah River below Thurmond Dam. Because there are numerous facilities discharging to the Harbor and many possible scenarios for achieving the total load, EPA will be working with the States of Georgia and South Carolina to develop a plan for assigning specific WLAs to each facility. The specific WLA's to each facility discharging to the River (below Thurmond Dam) and the Harbor, as determined by the States with EPA R4 support, will utilize both the Savannah River model and the Savannah Harbor model. The models will evaluate the transport and decay of TBODu from upstream sources and will allow the State agencies to allocate the loads appropriately.

6.3 Load Allocation (LA)

The load allocation is the portion of the total load that is provided to the non-NPDES sources of oxygen-demanding substances, including natural background sources. The majority of the non-NPDES loadings are from natural background sources. Man-induced non-NPDES sources are a minor contributor and are not considered in this TMDL. The man-induced wet weather storm water runoff to the Harbor is accounted for in the WLA, as the municipal sources of storm water runoff are covered by a NPDES permit. The available data does not indicate a significant upstream non-NPDES loading. If, at a later date, a significant upstream non-NPDES source is identified, the TMDL will be revised to account for this source.

The natural background loadings to the harbor are as follows:

- Upstream loads from natural riverine TBODu = 85,000 lbs/day
- Marsh loadings = 145,000 lbs/day

- Ocean boundary conditions for CBODu = 6 mg/l and Ammonia = 0.1 mg/l causes Harbor's natural DO levels to decrease due to the tidal flux for CBODu and ammonia into the Harbor system

6.4 Margin of Safety

A margin of safety (MOS) is a required component of a TMDL to accounts for the uncertainty in the relationship between the pollutant loads and the quality of the receiving waterbody. For Savannah Harbor, the amount of uncertainty is considered to be low. This system has been the recipient of extensive study, including extensive data collection, and model development by various state and federal agencies. The Savannah Harbor MOS is incorporated into the conservative critical condition assumptions used to develop the TMDL.

6.5 Seasonal Variation

Seasonal variation is incorporated in the Savannah Harbor TMDL by evaluating multiple years of data. For the hydrodynamic model, the years of 1997 through 2002 were evaluated. For the water quality model, summer time conditions for 1997, 1999, 2001 and 2002 were evaluated, including a complete 1999 annual model run.

6.6 TMDL

The TMDL to attain the current, applicable site-specific DO criterion an instantaneous minimum of no less than of no less than 3 mg/l throughout the water column is:

- TMDL = 230,000* lbs/day plus oxygen addition
 - LA = 230,000* lbs/day
 - WLA = 0 lbs/day plus
 - Oxygen Addition of 90,000 lbs/day oxygen to the Harbor system during critical condition periods.
 - Reduction = 100% of existing NPDES loads

* plus Ocean Boundary Conditions of CBODu = 6 mg/l and Ammonia = 0.1 mg/l

Until the site-specific criterion for DO for the Harbor is revised, this TMDL establishes the total loading to meet the applicable criterion. See Section 3 for an explanation of the criterion.

6.7 Alternate TMDL

EPA has determined that a revised site-specific criterion is appropriate for the Savannah Harbor, and recommended criterion levels are provided in this TMDL, (See Sections 3

and 6.2 for the recommended criterion.) The TMDL that would attain this recommended criterion is as follows:

- TMDL = 362,000 lbs/day
 - WLA = 132,000 lbs/day TBODu as a direct discharge to harbor
 - LA = 230,000 lbs/day TBODu
 - Reduction of approximately 30% of TBODu loading from 1999 existing loads NPDES discharges

The TMDL is expressed as a “gross” allocation to all NPDES sources in the basin that impact the Harbor DO levels. Because there are numerous facilities discharging oxygen demanding substances that reach the Harbor and many possible scenarios for achieving the total load reductions, EPA will be working with the States of Georgia and South Carolina to develop a plan for assigning specific WLAs for each facility.

REFERENCES

Georgia Rules and Regulations for Water Quality Control, Chapter 391-3-6-.03, Water Use Classifications and Water Quality Standards, July 2000

Sierra Club v. EPA & Hankinson USDC-ND-GA Atlanta Div. #1: 94-CV-2501-MHS, 1998.

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Development of the EFDC Hydrodynamic Model for the Savannah Harbor, August 2004. Report prepared for U.S.A.C.E. Savannah District and EPA Region 4. (Tetra Tech, Inc.)

Savannah Harbor Expansion Project TMDL 1999 River and Marsh Long-term Biochemical Oxygen Demand Results, June 2004. Report prepared for the Savannah Harbor Committee. (2004a MACTEC)

Port Wentworth Mill Effluent BOD Decay Characteristics, 2004. Research Report prepared for Weyerhaeuser. (Southern Environment Field Station, Weyerhaeuser)

WRDB Database Compilation of the Summer 1997 and 1999 Continuous Data Collection Results, August 2004. Prepared for EPA Region 4. (Tetra Tech, Inc.)

Draft Savannah Harbor Water Quality Model, August 2004. Prepared by EPA Region 4. (EPA Region 4)

APPENDIX A
Savannah Harbor Data Reports

A.1 Savannah Harbor TMDL Data Reports Summaries

Dissolved Oxygen Diffusion Study and Sediment Oxygen Demand Study, Savannah River, August 1999. Prepared by EPA Region 4 Science and Ecosystem Support Division. (1999 EPA Region 4)

EPA Region 4 Science and Ecosystem Support Division collected Sediment Oxygen Demand (SOD) measurements and estimates of oxygen diffusion (indirect reaeration measurements) for the critical areas in Savannah Harbor.

Wastewater Characterization Study, Lower Savannah River, Final Report, May 2000. Report prepared for the Savannah Harbor Committee. (MACTEC formerly LAWGIBB Group)

A wastewater characterization study of the 11 dischargers in the Lower Savannah River was conducted in summer 1999. This report provided the data to characterize the point source loads to the Lower Savannah River Estuary or Harbor.

Hydrodynamic and Water Quality Monitoring of the Lower Savannah River Estuary, August 2 through October 9, 1999. Engineering report prepared for the Georgia Ports Authority, Savannah, GA. (ATM 2000)

A monitoring program that encompassed 7 weeks of intensive sampling during the summer of 1999. See appendix A.2 for details.

Savannah Harbor Deepening Project, Tidal Marsh Studies Data Report, Volume 1, Volume 3 Marsh Vegetation Data. Report prepared for the Georgia Ports Authority, Savannah, GA. (ATM, 2003)

Development of the EFDC Hydrodynamic Model for the Savannah Harbor, March 2004. Report prepared for U.S.A.C.E. Savannah District and EPA Region 4. (Tetra Tech, Inc.)

For the hydrodynamic model development for the Savannah Harbor Estuary, it was critical to both clients (USACE and USEPA) that the model must meet the expectations discussed in the introduction section of this document. The Environmental Fluid Dynamics Code (EFDC) was selected to perform the hydrodynamic simulations because it was able to fulfill all of the requirements presented in the goals of the study.

The Savannah River Estuary is a highly complex estuarine system characterized by a branching channel network and extensive intra-tidal marsh areas. The combinations of a moderately energetic tidal environment and significant river basin drainage area result in a highly variable salinity regime that is a characteristic of stratified estuaries. Vertical density stratification significantly influences dissolved oxygen dynamics while both stratification, the landward intrusion of salinity, and the associated sub-tidal residual circulation strongly influence sedimentation dynamics. The complexities of the branching channel system dynamically coupled with the intra-tidal marshes result in

complex current amplitude and phase distributions, which further complicate the transport dynamics of the system. Increasing the depth of the navigational channel can impact local vertical mixing, increase landward salinity intrusion, and alter existing patterns of sediment deposition and resuspension. Predicting the transport of salinity, sediment, and water quality constituents in the Lower Savannah River necessitates the use of a three-dimensional modeling system, which includes hydrodynamic, sediment transport, and water quality components. The branching channel system and the presence of intra-tidal marshes further require a modeling system capable of representing complex open water regions dynamically coupled with marshes which dry and wet during the tidal cycles.

Draft Savannah Harbor Expansion Project Off-Shore Long-term Biochemical Oxygen Demand Results, May 2004. Report prepared for U.S. Army Corps of Engineers, Savannah District. (2004 MACTEC)

An analysis and results of 9 long term BOD samples collected by the Savannah Harbor Committee on September 24, 2004.

Savannah Harbor Expansion Project TMDL 1999 River and Marsh Long-term Biochemical Oxygen Demand Results, June 2004. Report prepared for the Savannah Harbor Committee. (2004a MACTEC)

Backup documentation for the 39 long term BOD samples collected during the 1999 intensive summer survey. (2000 ATM)

Port Wentworth Mill Effluent BOD Decay Characteristics, 2004. Research Report prepared for Weyerhaeuser. (Southern Environment Field Station, Weyerhaeuser)

Results and discussion of 8 long term BOD test conducted on Weyerhaeuser Port Wentworth Mill.

WRDB Database Compilation of the Summer 1997 and 1999 Continuous Data Collection Results, August 2004. Prepared for EPA Region 4. (Tetra Tech, Inc.)

WRDB was originally delivered to the Federal Agencies as part of ATM's data report. Since that time, USEPA Region 4 and Tetra Tech have not only made extensive updates to the program itself, but also to the datasets within the Savannah WRDB. There were several issues with the existing database, such as noon times were input as midnight, currents were considered to be positive with ebb and flood flows, and invalid salinity time series records. Additionally, the USGS data from 1997 through 2000 were input into the Savannah WRDB for salinity and water surface elevation. The water surface elevation data were corrected to the National Geodetic Vertical Datum (or Mean Sea Level of 1929) based on USGS report adjustments.

Complete details of these assessments are included in the administrative record of the TMDLs

A.2 Data Summary for Savannah Harbor (2004 Tetra Tech)

There were three main datasets used in the calibration and confirmation of the hydrodynamic and water quality models for Savannah Harbor. More importantly, these datasets allowed for analysis to understand processes that drive the hydrodynamics (salinity intrusion, horizontal and vertical mixing, retention time, marsh responses, spring and neap tides, and currents) and the water quality (BOD decay, nitrification, marsh loads, upstream loads, stormwater loads). The Georgia Ports Authority (GPA) conducted two large, extensive monitoring efforts during the summers of 1997 and 1999. The 1997 field effort was conducted in August and September and the 1999 effort was conducted from July through October. These two field efforts consisted of dive crews, field sampling crews, and EPA conducting continuous monitoring of dissolved oxygen, pH, water and air temperature, conductivity (salinity), water surface elevation, and velocity. The field efforts also included water chemistry sampling, LTBD measurements, marsh sampling, flow transects, 24-hour sampling, vertical profiling, and longitudinal profiling.

EPA conducted a study in 1999 to measure sediment oxygen demand (SOD) and reaeration. In addition to the two GPA field studies, the USGS continues to monitor at eight locations in the Savannah River and Harbor areas.

There are five locations where continuous water level is measured, four locations of salinity, and one location for flow. These stations have been active since the early 1980s and continue to operate today. Table 4 displays a list of all of the stations and locations summarized by the three field efforts in Savannah Harbor.

The USGS data allows for examination of the long term response of flow, water surface elevation, and salinity respond to rainfall and atmospheric conditions in the Savannah River Basin. Especially since Georgia experienced a 5-year drought from 1998 through 2002 (Barber and Stamey, 2000-2002) and a large rainfall period in 2003.

The GPA studies were intensive efforts during a short, summer periods in 1997 and 1999. The main stations used in the calibration were from the GPA studies in 1997 and 1999. Figure 2 shows the locations of the USGS stations and Figure 3 shows the locations of the 1997 and 1999 stations. Table 4 gives an overall list of the locations of these stations and the vertical placement in the water column which will be critical for the salinity calibration in the subsequent sections. The Clio flow gage is not shown in Figure 2.

The vertical locations described in Table 4 are generally described. For the GPA 1999 stations in particular, the bottom meters were deployed on concrete pedestals that were mounted 1 meter from the bottom. The surface meters were deployed on buoys of some nature and were

mounted 1 meter below the surface. For the 1997 GPA stations, this was generally true, however, some of the bridge locations such as BR-05 and FR-09 were fixed to the bridge piers and therefore were not consistently a bottom meter at all times.

Table 4 Description of USGS/GPA Stations in the Savannah River Estuary

Station ID	Station Description	River Mile	Agency	Parameters	1997 Location ¹	1999 Location ¹
BR-05	Back River at Hwy 17	14.5	GPA	S, T, WL	Bottom	Bottom
FR-02	Front River	4.5	GPA	S, T, WL	Surface & Bottom	Surface & Bottom
FR-04	Front River	10.4	GPA	S, T, WL, C	Surface & Bottom	Surface & Bottom
FR-06	Front River	16.6	GPA	S, T, WL, C	Surface & Bottom	Surface & Bottom
FR-08	Front River	20.5	GPA	S, T, WL, C	Surface & Bottom	Surface & Bottom
FR-09	Front River	21.5	GPA	S, T, WL	Bottom	Surface & Bottom
FR-11	Front River	24.7	GPA	S, T, WL	Bottom	
FR-11R	Front River, Revised 1999	23.4	GPA	S, T, WL		Bottom
FR-21	Front River	13.9	GPA	S, T, WL		Surface & Bottom
FR-22	Front River	18.7	GPA	S, T, WL		Surface & Bottom
FR-26	Front River	0.8	GPA	S, T, WL		Surface & Bottom
BR-07	Back River	18.9	GPA	S, T, WL	Bottom	Surface
LBR-13	Little Back River	26.6	GPA	S, T, WL	Bottom	
LBR-15	Little Back River	20.9	GPA	S, T, WL	Mid-Depth	Surface
MR-10	Middle River	21.8	GPA	S, T, WL	Bottom	Surface
MR-12	Middle River	24.4	GPA	S, T, WL	Bottom	
MR-12R	Middle River, Revised 1999	23.7	GPA	S, T, WL		Surface
SC-03	South Channel	5.5	GPA	S, T, WL	Bottom	Bottom
SR-14	Savannah River	27.7	GPA	S, T, WL	Bottom	Bottom
02198920	Front River at Houlihan Bridge	21.5	USGS	S, WL	Mid-Depth ²	Mid-Depth ²
02198977	Front River at Broad Street	14.6	USGS	WL	Mid-Depth ²	Mid-Depth ²
02198980	Front River at Fort Pulaski	0.8	USGS	WL	Mid-Depth ²	Mid-Depth ²
021989784	Little Back River at Lucknow Canal	24.2	USGS	S	Mid-Depth ²	Mid-Depth ²
02198979	Little Back River at Limehouse Cr	24.1	USGS	WL	Mid-Depth ²	Mid-Depth ²
021989791	Little Back River at USF&W Dock	22.1	USGS	S	Mid-Depth ²	Mid-Depth ²
02198500	Savannah River near Clyo, GA	61.0	USGS	Q	Mid-Depth ²	Mid-Depth ²
02198840	Savannah River at I-95 Bridge	27.7	USGS	S, WL	Mid-Depth ²	Mid-Depth ²

NOTES: Parameters - S=Salinity, T=Temperature, WL=Water Level, C=Currents, Q=Flow
1. Location is describing vertical water column location.
2. Mid-Depth = 2.7 feet below Mean Low Water (MLW).

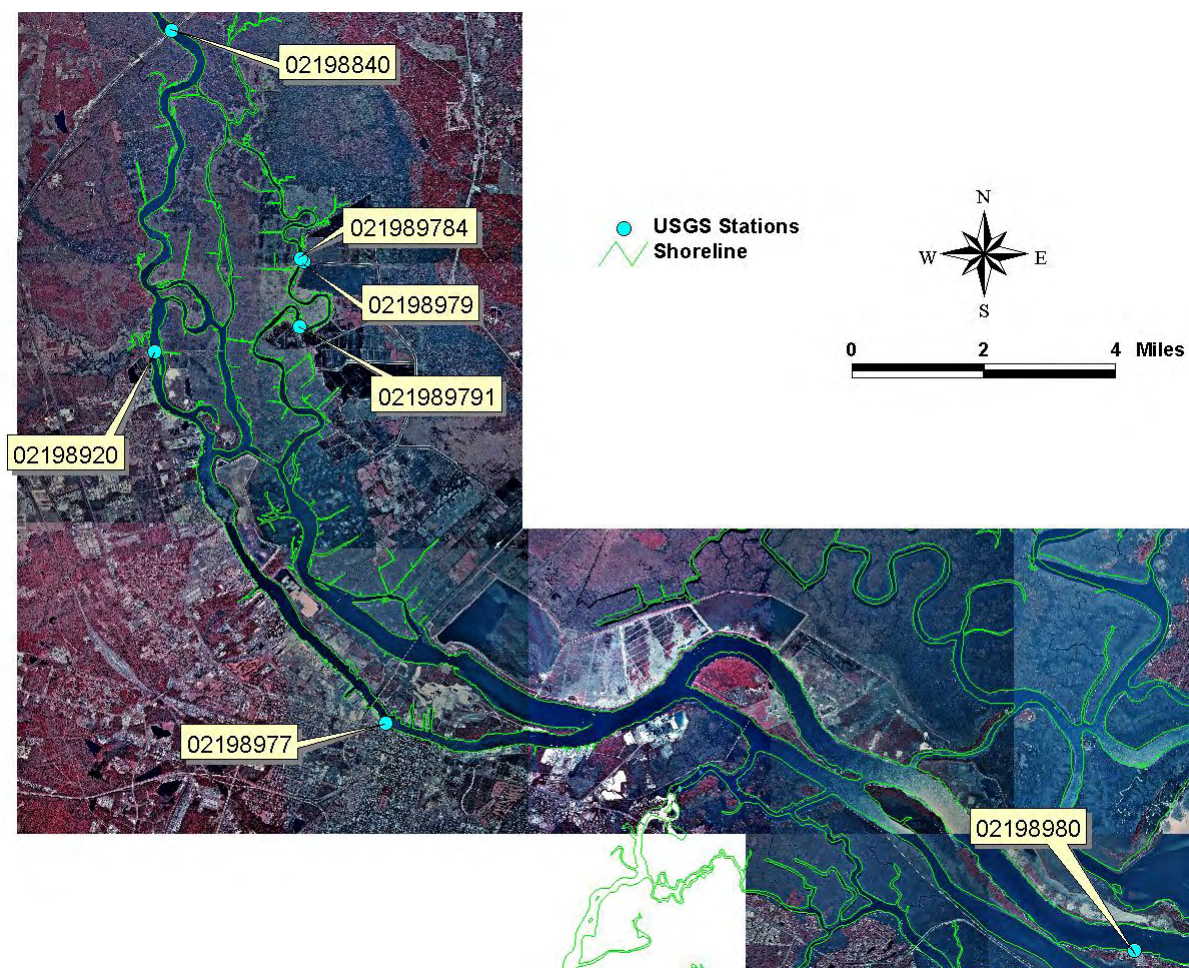


Figure 2 Location Map of USGS Stations in the Savannah Harbor Estuary

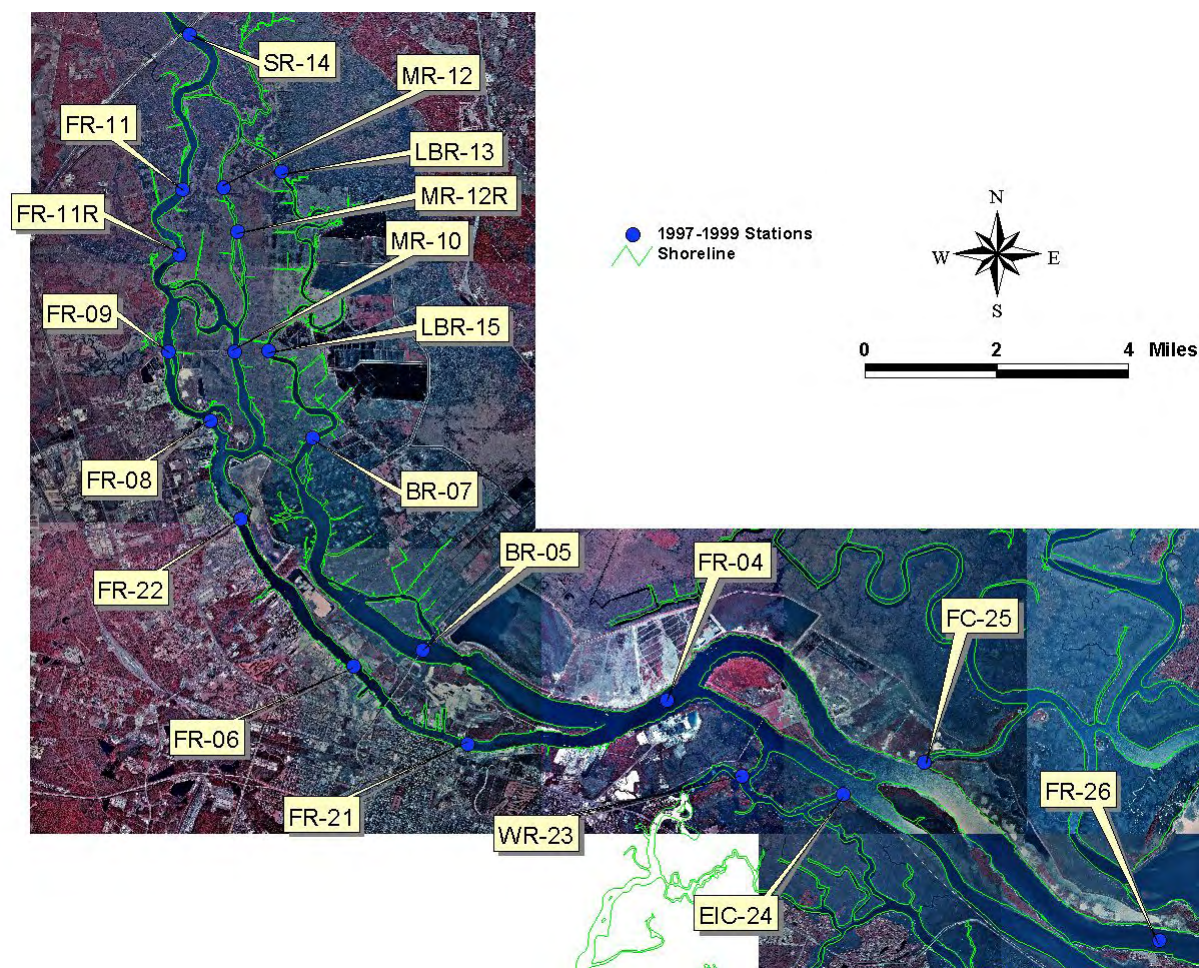


Figure 3 Location Map of 1997 & 1999 Stations in the Savannah Harbor Estuary

The Water Resources Database (WRDB) was used to archive, analyze, and pull data into the model post-processor. WRDB is a comprehensive data storage system capable of handling a vast amount of data, accommodating a wide variety of data types and diverse information, and presenting data conveniently and efficiently. WRDB was originally developed by the Georgia Environmental Protection Division (GAEPD) in association with USEPA Region 4 to address the imposing data management challenges presented by the Chattahoochee River Modeling Project. Since its inception, WRDB has been enhanced a number of times and applied to numerous projects in Region 4. A main goal of the system has been to provide data management and analysis tools to users possessing an assortment of professional specialties and a variety of software skill levels. WRDB version 4.5 was used to build the Savannah Harbor database.

All water surface elevation data were corrected to the National Geodetic Vertical Datum (or Mean Sea Level of 1929) based on USGS report adjustments (Stokes, 2002).

APPENDIX B

Hydrodynamic Model Summary

B.1 Savannah Harbor EFDC Hydrodynamic Model Summary (2004 Tetra Tech)

For the hydrodynamic model development for the Savannah Harbor Estuary, it was critical to both clients (USACE and USEPA) that the model must meet the expectations discussed in the introduction section of this document. The Environmental Fluid Dynamics Code (EFDC) was selected to perform the hydrodynamic simulations because it was able to fulfill all of the requirements presented in the goals of the study. EFDC has been applied on many waterbodies within USEPA Region 4 for TMDL and permitting modeling projects including complex systems such as Mobile Bay AL, Neuse River and Estuary NC, Brunswick Harbor GA, Fenholloway River and Estuary FL, Loxahatchee River and Estuary FL, Indian River Lagoon FL, Lake Worth Lagoon FL, Florida Bay, Lake Okeechobee FL, Cape Fear River NC, and St. Johns River FL. EFDC has proven to capture the complex hydrodynamics in similar systems such as the Savannah Harbor and is currently being applied by Tetra Tech in the Charleston Harbor SC.

With many of the EFDC applications in Region 4 being tied to the regulatory TMDL process, Tetra Tech has delivered the model to state and federal personnel to run the model for regulatory management decisions. Although a number of models provide some of the features necessary for modeling hydrodynamics, water quality, and sediment transport in the Savannah River Estuary, the EFDC hydrodynamic and sediment transport model, linked with the WASP water quality model provides the most appropriate combination of features necessary for this study.

The EFDC model comprises an advanced three-dimensional surface water modeling system for hydrodynamic and reactive transport simulations of rivers, lakes, reservoirs, wetland systems, estuaries and the coastal ocean. The modeling system was originally developed at the Virginia Institute of Marine Science as part of a long-term research program to develop operational models for resource management applications in Virginia's estuarine and coastal waters (Hamrick, 1992). Since the EFDC model is public domain, with current users including universities, governmental agencies and engineering consultants. The following sub-sections describe the model's capabilities and previous applications and its theoretical and computational formulations.

The EFDC model's hydrodynamic model component is based on the three-dimensional shallow water equations and includes dynamically coupled salinity and temperature transport. Salinity and temperature transport are simultaneously solved with the hydrodynamics and dynamically coupled through an equation of state.. Additional hydrodynamic component features include the Mellor-Yamada turbulence closure formulation, simulation of drying and wetting, representation of hydraulic control structures, vegetation resistance, wave-current boundary layers and wave induced currents, and dynamic time stepping. The EFDC hydrodynamic model can run independently of a water quality model. The EFDC model simulates the hydrodynamic and constituent transport and then writes a hydrodynamic linkage file for a water quality model such as the WASP6 model. This model linkage, from EFDC hydrodynamics to WASP7 water quality, has been applied on many USEPA Region 4 projects in support of TMDLs and has been well tested (Wool, 2003). EFDC is also directly linked to Waterways Experiment Station CEQUAL- ICM.

The Savannah River Estuary is a highly complex estuarine system characterized by a branching channel network and extensive intra-tidal marsh areas. The combinations of a moderately energetic tidal environment and significant river basin drainage area result in a highly variable salinity regime that is a characteristic of stratified estuaries. Vertical density stratification significantly influences dissolved oxygen dynamics while both stratification, the landward intrusion of salinity, and the associated sub-tidal residual circulation strongly influence sedimentation dynamics. The complexities of the branching channel system dynamically coupled with the intra-tidal marshes result in complex current amplitude and phase distributions, which further complicate the transport dynamics of the system. Increasing the depth of the navigational channel can impact local vertical mixing, increase landward salinity intrusion, and alter existing patterns of sediment deposition and resuspension. Predicting the transport of salinity, sediment, and water quality constituents in the Lower Savannah River necessitates the use of a three-dimensional modeling system, which includes hydrodynamic, sediment transport, and water quality components. The branching channel system and the presence of intra-tidal marshes further require a modeling system capable of representing complex open water regions dynamically coupled with marshes which dry and wet during the tidal cycles.

Flow, velocity, surface elevation, salinity and temperature calibration details are included in the EFDC modeling report for Savannah Harbor (2004 Tetra Tech). In addition based on comments from reviewers the harbor model was enhanced to include the inputs for the water withdraws, point source discharges and temperature loadings.

B.1.1 Flow Modifications

The Savannah Hydrodynamic Model includes major point sources / sinks discharges and withdrawals. The corresponding information was presented to Tetra Tech Inc by partnering federal, state and local agencies. Some of these discharges/withdrawals were presented as annual averages, and for some of them the time series measurements were available. The averaged discharges / withdrawals are presented in Table 1, and time series discharges/withdrawals are referred in Table 2.

Table 1. Annually averaged point sources discharges/withdrawals for Savannah River Model

Point Source Discharge/Withdrawal	Location Cell (I, J)	Flow (m ³ /s)
Smurfit discharge	I=5, J=52	0.113906
Garden City discharge	I=5, J=46	0.049943
Whilshire discharge	I=5, J=45	0.135811
Travis Field discharge	I=5, J=45	0.033296
President Street discharge	I=5, J=39	0.823628
Englehard discharge	I=5, J=38	0.042496
Kerr McGee #1 discharge	I=4, J=36	0.56953

Kerr McGee #2 discharge	I=4, J=36	0.122668
Savannah Electric Plant Macintosh discharge	I=5, J=91	5.7
Savannah Electric Port Wentworth discharge	I=5, J=49	11.3
Savannah Electric Plant Macintosh withdrawal	I=5, J=92	-5.7
Savannah Electric Port Wentworth withdrawal	I=5, J=49	-11.3
Riverside Power Plant discharge	I=5, J=40	2.13
Riverside Power Plant withdrawal	I=5, J=40	-2.13

Table 2. Time series discharges/withdrawals for Savannah River Model

Point Source Discharge/Withdrawal	Location Cell (I, J)	Flow (m ³ /s)
Hardeville discharge	I=5, J=76	Time Series
Fort James discharge	I=5, J=90	Time Series
Savannah Industrial & Domestic Water Supply withdrawal	I=28, J=120	Time Series
Beauford-Jasper Water Authority withdrawal	I=5, J=84	Time Series
International Paper discharge	I=7, J=44	Time Series

Estimates of potential freshwater flow from watersheds (based on values of their areas) surrounding the Savannah River from Clyo down to Savannah Harbor support increasing the upstream boundary freshwater river flow by 10% and including two additional sources of freshwater flow at: Union Creek (I=21,J=59) – 5m³/s, and Front River (I=5,J=52) – 10m³/s.

B.1.2 Heat Load Modifications

Heat loads from three power plants: Savannah Electric Plant Macintosh, Savannah Electric Port Wentworth and Riverside Power Plant were calculated based on estimates of their discharges by pump capacities for river water withdrawal, and capacities of power generation.

The “heat rate” for coal-fired steam-electric power plants is about 10,000 BTU heat input per Kw-hr of electricity generated (about 34-percent efficient). One Kw-hr is equivalent to 3413 BTU. Therefore, generating one Kw-hr of electricity results in a heat load of 6587 BTU (10,000 – 3413) that must be rejected to the environment. Assuming 95% of this heat is rejected to the river (with the other 5 % going directly to the local atmosphere), one Kw-hr of generated electricity results in a heat load of about 6300 BTU to the river. One BTU raises the temperature of one pound of water one degree Fahrenheit.

Based on these assumptions and available data we can calculate increasing of temperature in discharged power plants’ waters by following formula

$$\Delta^{\circ}C = P * 6300 * a * Q^{-1} * b$$

where $\Delta^{\circ}C$ is a increasing of temperature of discharged waters (degree of Celsius); P is a power generation (Kw-hr); $a=0.55$ is a conversion coefficient of temperature change from

Fahrenheit to Celsius; Q is a power plant discharge (m^3/hr); $b=0.0004536$ is a conversion coefficient from a pound to a tonne.

We did not have detailed information about power generation of the Riverside Power Plant but the estimates that it is not significant. So we assumed the temperature increase equals the one for Savannah Electric Port Wentworth.

Power Plant	Power Generation (Kw-Hr)	Water Discharge (m^3/s)	$\Delta^{\circ}\text{C}$
Savannah Electric Plant Macintosh	800,000	5.7	61.4
Savannah Electric Port Wentworth	160,000	11.27	6.2
Riverside Power Plant		2.13	6.2

The temperature of discharged waters of power plants was assumed to be the sum of Clyo water temperature time series plus $\Delta^{\circ}\text{C}$. These new calculated time series were placed into TSER.INP file and use to determine the heat load of the Savannah power.

APPENDIX C

Fact Sheet describing the Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater)

Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras Fact Sheet

United States
Environmental Protection
Agency

Office of Water
4304

EPA-822-F-99-009
October 2000

Summary

The U.S. Environmental Protection Agency (EPA) is recommending ambient water quality criteria for dissolved oxygen that will protect coastal and estuarine animals in the Virginian Province (Cape Cod, MA to Cape Hatteras, NC). The criteria combine features of traditional water quality criteria with a new biological framework that integrates exposure to low dissolved oxygen over time rather than averaging dissolved oxygen exposure conditions into one single value. The criteria also establish protection limits for different life stages (i.e., larvae versus juveniles and adults).

Background

EPA is recommending ambient water quality criteria for dissolved oxygen (saltwater) to protect coastal and estuarine animals in the Virginian Province (Cape Cod, MA to Cape Hatteras, NC) from low dissolved oxygen levels (DO). EPA has not issued saltwater DO criteria before because information on the adverse effects of low DO on aquatic organisms was insufficient. The new DO criteria result from a 10-year research effort. The water quality criteria represent EPA's best estimates, based on the data available, of DO concentrations necessary to protect aquatic life and uses associated with aquatic life. States, territories, and authorized tribes may use these water quality criteria as guidance in setting water quality standards for coastal and estuarine waters as required by Section 304(a) of the Clean Water Act.

Why is EPA publishing dissolved oxygen criteria?

EPA is publishing the saltwater DO criteria to protect organisms and their uses from the adverse effects of low DO conditions. The Agency developed these criteria because hypoxia (low dissolved oxygen) is a significant problem for coastal waters that receive a lot of runoff that contain nutrients (for example, nitrogen and phosphorous and other oxygen-demanding biological wastes). Excessive nutrients in aquatic systems stimulate algal growth, which in turn uses up the oxygen needed to maintain healthy fish and shellfish populations.

EPA's Environmental Monitoring and Assessment Program (EMAP) for the estuaries in the Virginian Province (defined as Cape Cod to Cape Hatteras) has shown that 25% of the area is exposed to some

dissolved oxygen concentrations of less than 5 mg/L. Long periods of DO below 5 mg/L can harm larval life stages for many fish and shellfish species. Field data collected through EMAP has shown a correlation between many of the biologically degraded benthic areas and low dissolved oxygen in the lower water column. These observations serve to emphasize the fact that hypoxia is a serious concern for the Virginian Province and other coastal locations in the United States. Hypoxia is regulated primarily by controlling (typically a reduction) nutrients (largely nitrogen) put into a water body. The DO criteria identify waters with DO problems and can form the basis for necessary reductions in nutrient levels.

Saltwater DO criteria for coastal and estuarine waters will help states, territories, and authorized tribes develop and adopt DO water quality standards. These standards, in turn, may provide a basis for:

- appropriate total maximum daily loads (TMDLs) for nutrient control,
- numerical discharge limits in permits established under the National Pollutant Discharge Elimination System (NPDES),
- appropriate nonpoint source runoff controls,
- needed wetlands protection, and
- other water resources management efforts.

Environmental planners can also use the approach to evaluate conditions under different management scenarios and make better decisions. The general public will benefit because the DO criteria will help EPA, the states, and authorized tribes achieve the Clean Water Act goal of "fishable and swimmable" waters.

What are the criteria limits?

Dissolved oxygen criteria apply to both continuous and cyclic low DO conditions. If the DO conditions are always above the chronic criterion for growth (4.8 mg/L), the aquatic life at that location should not be harmed. If the DO conditions at a site are below the juvenile/adult survival criterion (2.3 mg/L), there is not enough DO to protect aquatic life. When persistent DO conditions are between these two values, further evaluation of duration and intensity of low DO is needed to determine whether the level of oxygen can support a healthy aquatic life community (see Figure 1).

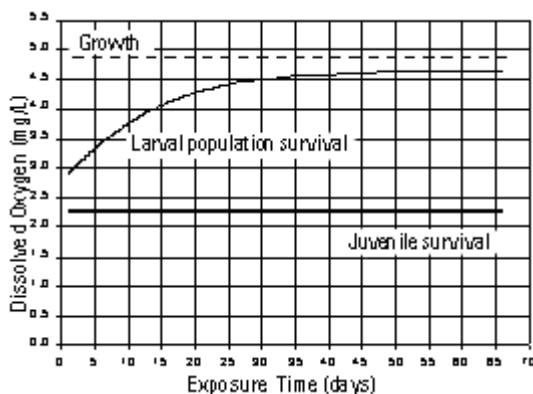


Figure 1. Summary of DO Criteria for Persistent Exposure. Lines are lower bound limits on protective DO concentrations. The chronic growth limit may be violated for a specific number of days provided the chronic larval recruitment limit is not violated.

The approach for episodic or cyclic low DO conditions requires that the DO be directly measured over a daily cycle or that the daily DO cycle be estimated. The cyclic pattern is then compared to allowable

levels to determine suitability of DO conditions for the juvenile/adult survival, larval growth, and larval recruitment endpoints.

Where do these criteria apply?

These water quality criteria recommendations apply to coastal waters (defined as within three miles from shore under section 502(8) of the CWA) of the Virginian Province (Cape Cod, MA to Cape Hatteras, NC) of the Atlantic coast of the United States. Under the CWA, states, territories, and tribes must adopt water quality criteria to protect designated uses. EPA has promulgated regulations to implement this requirement (see 40 CFR 131). This criteria document does not substitute for those provisions or regulations, nor is it a regulation. Risk managers can apply the criteria to other coastal waters if they can scientifically determine that their location-specific biological, physical, and water quality conditions are comparable to those of the Virginian Province.

What are the Endangered or Threatened Species Policy Recommendations?

It may be appropriate to derive site-specific DO criteria when a threatened or endangered species is at a site, and when data indicates that it is sensitive at concentrations above the recommended criteria.

What are the future activities related to these criteria?

EPA will publish an addendum to this criteria document to address implementation issues in greater detail. Topics may include:

- accuracy of monitoring data,
- identification of biological effects,
- importance of spacial extent of low DO,
- application to differing salinities, and
- consideration of threatened and endangered species.

Environmental managers should consider all of these issues when they adopt and implement DO water quality standards. The planned addendum may use real world examples to illustrate these implementation issues. It will also discuss applying this guidance to marine waters outside the Virginian Province.

How do I get a copy of the criteria document?

You can get a copy of the complete document, *Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras* (EPA-822-R-00-012) by calling EPA's National Service Center for Environmental Publications (NSCEP) at 1-800-490-9198. You can also get it from EPA's web site at <http://www.epa.gov/waterscience/standards/dissolved/>.

For more information about the development of the criteria, contact

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APPENDIX D

Savannah River Upstream Dischargers Permit Limits and Oxygen Demanding Loads

Facility name	Stream	Flow	Current Permit Limits			
			BOD5	BOD5	NH3	Nitrogen
			mg/l	lbs/day	mg/l	lbs/day
Georgia		mgd				
City of Harlem	Uchee Creek	0.25	30	---	---	---
Richmond County						
Spirit Creek	Spirit Creek	2.24	30	---	17.4	---
Gracewood School and Hospital	Spirit Creek	0.50	30	---	17.4	---
Columbia County						
Reed Creek	Reed Creek	4.60	10	---	2.0	---
Columbia County						
Crawford Creek	Crawford Creek	1.50	30	---	1.2	---
City of Augusta	Butler Creek	46.10	10	---	1.5	---
Fort Gordon	McCoy Creek	4.00	30	---	---	---
City of Thomson	Brier Creek	2.50	15	---	5.0	---
City of Sardis	Brier Creek	0.20	20	---	5.0	---
City of Waynesboro	Brier Creek	2.00	12	---	1.9	---
City of Sylvania	Ebenezer Creek	1.51	30	---	17.4	---
City of Springfield	Ebenezer Creek	0.50	25	---	5.0	---
Columbia County						
Little River	Savannah River	3.00	15	---	8.7	---
International Paper	Savannah River	---	---	30000	---	---
DSM Chemicals	Savannah River	---	---	868	---	6000
NIPRO	Savannah River	---	---	3300	---	6000
Arcadian	Savannah River	---	---	---	---	2833
Fort James Paper	Savannah River	---	---	9560	---	---
Georgia Power Co. Plant Votgle	Savannah River	---	---	---	---	---

Savannah Electric Plant McIntosh	Savannah River	---	---	---	---	---
South Carolina						
City of Aiken Horse Creek	Horse Creek	26.0	33	7156	11.0	---
Kimberly-Clark	Savannah River	11.2	43	4031	---	---
Savannah River Site	Savannah River					
Town of Allendale	Savannah River	4.0	25	834	20.0	---
Town of Hardeeville	Savannah River	1.0	30	253	---	---
Clariant Corporation	Savannah River	1.8	37	564	---	---
SC Electric and Gas, Urquhart	Savannah River	142.9	---	---	---	---

Oxygen Demanding Load Based on Current Permit Limits						
Facility name	Stream	Flow mgd	f-Ratio est	CBODu lbs/day	NBODu lbs/day	TBODu lbs/day
Georgia						
City of Harlem	Uchee Creek	0.25	2	125		125
Richmond County Spirit Creek	Spirit Creek	2.24	2	1121	663	1784
Gracewood School and Hospital	Spirit Creek	0.50	2	250	663	913
Columbia County Reed Creek	Reed Creek	4.60	4	1535	76	1611
Columbia County Crawford Creek	Crawford Creek	1.50	2	751	46	797
City of Augusta	Butler Creek	46.10	4	15379	57	15436
Fort Gordon	McCoy Creek	4.00	2	2002		2002
City of Thomson	Brier Creek	2.50	3.5	1095	191	1285
City of Sardis	Brier Creek	0.20	3	100	191	291
City of Waynesboro	Brier Creek	2.00	3.5	701	72	773
City of Sylvania	Ebenezer Creek	1.51	2	756	663	1419
City of Springfield	Ebenezer Creek	0.50	2	209	191	399
Columbia County Little River	Savannah River	3.00	3.5	1314	332	1645
International Paper	Savannah River	---	6	180000		180000
DSM Chemicals	Savannah River	---	3	2604	13710	16314
NIPRO	Savannah River	---	3	9900	13710	23610
Arcadian	Savannah River	---	---		12947	12947
Georgia Power Co. Plant Votgle	Savannah River	---	---			0

Savannah Electric Plant McIntosh	Savannah River	---	---			0
South Carolina						
City of Aiken Horse Creek	Horse Creek	26.0	3	21467	419	21886
Kimberly- Clark	Savannah River	11.2	3	12093		12093
Savannah River Site	Savannah River					0
Town of Allendale	Savannah River	4.0	3	2502	762	3264
Clariant Corporation	Savannah River	1.8	3	1693		1693
SC Electric and Gas, Urquhart	Savannah River	142.9				
Total =						300,250

APPENDIX E

Development of the Marsh Areas for the Models

E.1 EFDC Hydrodynamic Model

The adjacent marsh areas in the Lower Savannah River and Estuary (Harbor) play a significant role on the dissolved oxygen concentrations in the Front River. The marsh areas are also significant for the hydrodynamics but mainly affect the salinity transport on the Middle and Little Back Rivers. Therefore, it was determined that the marsh areas were necessary for capturing the salinity trends in the upper part of the estuary. The modeled marsh areas would also provide a mechanism to simulate loadings from the marsh areas into Savannah Harbor. A simple, but comprehensive solution was developed to handle the marsh areas in the EFDC hydrodynamic and WASP water quality models. The EFDC model included the marsh areas by relying on information in ATM's "Tidal Marsh Studies Data Report" Volumes 1 and 3 (2003). In the report, ten separate marsh zones, called Q zones, were delineated based on vegetation zones measured by ATM's field studies. For each Q zone, the flooding frequency and duration were determined based on water surface elevation and marsh survey transects. Average depths in each of the Q zones were also computed based on longterm tidal records. Table X-1 summarizes the information for each of the Q zones along with the major connection to the harbor (or river), such as Front River (FR), Back River (BR), Middle River (MR), and Little Back River (LBR).

Table 5 Flooding Frequency, Duration, and Average Depth by Q Zone (ATM, 2003)

River	Q Zone	Flooding % Freq	Flooding % Duration	Avg Depth (ft)	Avg Depth (m)	Elev (ft) NGVD
FR	Q1	30.9	5.6	0.39	0.12	5.05
BR	Q2	91.2	22.6	0.81	0.25	3.69
BR	Q3	63.2	14.7	0.60	0.18	4.29
LBR	Q4	75.0	19.2	0.69	0.21	4.20
MR	Q5	62.9	16.3	0.65	0.20	4.47
MR	Q6	56.5	12.9	0.51	0.16	4.64
FR	Q7	91.8	26.8	0.95	0.29	3.83
LBR	Q8	60.5	13.8	0.46	0.14	4.68
MR	Q9	79.6	21.5	0.70	0.21	4.18
MR	Q10	75.2	19.7	0.72	0.22	4.31

The ATM report also had total acreages calculated for secondary (or feeder) channels, river, and marshes for each of the ten Q zones. This allowed for the marsh exchange areas to be compartmentalized into three separate volumes of water (river, feeder, and marsh). Total volume for each Q zone was then calculated based on actual areas and actual depths reported in Table X-1. For the feeder or secondary channels, an estimated depth of 1.2 meters was used based on field experience. Since the model stability was essential for model run times and for a reasonable management tool for the harbor, the model depths were then exaggerated to be larger than reality, but meanwhile, holding the total actual volume of the marsh and feeder channel to be consistent. Then, the model areas were re-calculated based on new depths. After

calculations, all feeder channels were 3.0 meters and marsh areas were 1.4 meters deep. Table X-2 shows the actual areas reported by ATM and the subsequent marsh area calculations. The EFDC model was then extended with 1 marsh cell and 1 feeder cell that were represented with the exact surface areas in Table X-2. These areas can be reviewed in the “dxdy.inp” input file for EFDC.

Figure X-1 displays the coarse grid with the additions of the ten marsh areas. Q6 was added to Q9 and placed on the Middle River. When Q6 was placed on the Front River where it was delineated by ATM based on the vegetation, the marsh area played a large role in the mixing of salinity on the Front River near Houlihan Bridge. Therefore, the surface area and volume were added to Q9 on the Middle River and the totals were consistent with the reported marsh data reports.

Table 6 Marsh Area Calculations used in the EFDC Model

Q zone	Waterbody	Actual Area (acres)	Actual Area (m ²)	Actual Depth (m)	Actual Volume (m ³)	Model Depth (m)	Model Area (m ²)	Model Volume (m ³)
Q1	CHANNEL	15	59,870	1.2	72,994	3.0	24,331	72,994
	MARSH	490	1,981,290	0.12	235,520	1.4	168,228	235,520
Q2	CHANNEL	187	755,863	1.2	921,549	3.0	307,183	921,549
	MARSH	2,190	8,861,825	0.25	2,187,878	1.4	1,562,770	2,187,878
Q3	CHANNEL	89	360,733	1.2	439,806	3.0	146,602	439,806
	MARSH	1,363	5,516,392	0.18	1,008,838	1.4	720,598	1,008,838
Q4	CHANNEL	12	46,544	1.2	56,746	3.0	18,915	56,746
	MARSH	336	1,359,504	0.21	285,920	1.4	204,229	285,920
Q5	CHANNEL	8	33,334	1.2	40,641	3.0	13,547	40,641
	MARSH	210	851,168	0.20	168,633	1.4	120,452	168,633
Q6	CHANNEL	8	33,080	1.2	40,331	3.0	13,444	40,331
	MARSH	489	1,977,169	0.16	307,347	1.4	219,534	307,347
Q7	CHANNEL	9	35,485	1.2	43,264	3.0	14,421	43,264
	MARSH	247	1,000,219	0.29	289,623	1.4	206,874	289,623
Q8	CHANNEL	29	117,309	1.2	143,023	3.0	47,674	143,023
	MARSH	682	2,760,700	0.14	387,072	1.4	276,480	387,072
Q9	CHANNEL	5	18,996	1.2	23,160	3.0	7,720	23,160
	MARSH	457	1,849,307	0.21	394,568	1.4	281,834	394,568
Q10	CHANNEL	13	53,515	1.2	65,245	3.0	21,748	65,245
	MARSH	409	1,656,197	0.22	363,462	1.4	259,616	363,462

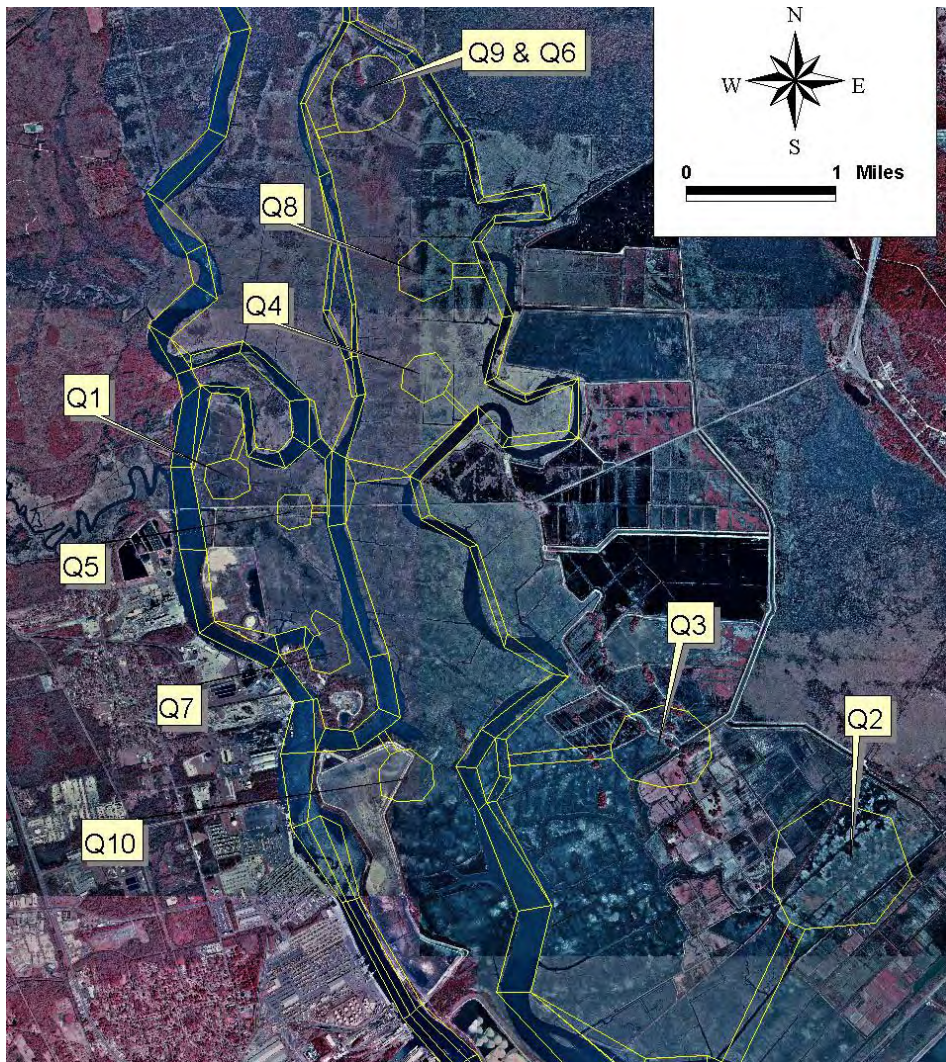


Figure 4 EFDC Marsh Areas

E.2 WASP Water Quality Model

In order to quantify the exchange of organic material exported from marshes to the open water of the Savannah Harbor, previous studies were reviewed to develop appropriate loading rates from the ten Q zones discussed in the hydrodynamic section. The following previous studies were reviewed and used to quantify the marsh loadings:

- GPA field data during Summer of 1999 – marsh data (ATM, 2000).
- Maybank Project: A Study of the Intertidal Marshes and Streams. US EPA Environmental Services Division, Athens, Georgia, May 1984 (EPA, 1984).
- Burke III, Roy 1984. Proposed Protocol for: Incorporating the Effects of a Spartine Salt Marsh into a Simplified Water Quality Model of Adjacent Tidal Waters in Georgia. US EPA, Region 4 (Burke, 1984).

- Nutrient Dynamics and Water Quality Interactions in the Goose Creek Sub-Basin of the Charleston Harbor Estuary. Department of Environmental Health Science University of South Carolina, Columbia, S.C. October 1996 (McKellar, 1996).
- Nixon, Scott W and Virginia Lee. Wetlands and Water Quality. Technical Report Y-86-2, October 1986 (Nixon, 1986).

Results of all LTBOB sampling at Marsh Exchange Transect sites in the lower Savannah River (ATM, 2000) demonstrate that all BOB samples collected during mid-ebbing tides exceed the values of BOB collected during corresponding mid-flooding tides. This indicates that marshes in Savannah Harbor export organic matter to open waters of the harbor. On basis of data available in six figures, which demonstrate the field research results, the clear conclusion about nitrogen BOB (NBOB) importing properties of the salt marsh can be made only for three of the available five Marsh Exchange Transects.

Data collected during the Maybank study (EPA, 1984), found that the marshes are normal processors of nutrients and make net contribution of nutrients and protein-enriched detritus to the estuary. A primary source of detritus for export to the estuary would be the marsh macrophytes growing in the studied area. These conclusions were developed from water samples analyzed for ammonia (NH_3), nitrite-nitrate ($\text{NO}_2\text{-NO}_3$), total Kjeldahl nitrogen (TKN), total phosphorus (TP), and total organic carbon (TOC) and continuous records of dissolved oxygen and temperature.

Intensive tidal transport studies of water and nutrient exchange between tidal wetlands and estuarine waters were conducted at Browns Marsh on the Goose Creek, a tributary to the Cooper River (McKellar, 1996). The data collected found consistent trends of nitrogen uptake by the tidal marshes, which removed 20-34% of the nitrate flowing across the marsh during each tidal cycle. Nitrate uptake by the wetlands exhibited distinct seasonal patterns of daily removal, yielding annual uptake of 8.4 g N/m^2 . Ammonium exchanges also suggested a tendency for net annual export of $5.7 \text{ g N/(m}^2 \text{ year)}$. Organic matter exchanges in the wetlands were also variable but displayed a strong tendency toward net export ($57.3 \text{ g C/(m}^2 \text{ year)}$). Algal biomass (chlorophyll-a) was exported from the marsh during the winter ($0.1\text{-}0.8 \text{ mg/(m}^2 \text{ day)}$) and imported during the late summer and fall ($1.4\text{-}1.9 \text{ mg/(m}^2 \text{ day)}$) yielding an approximate annual balance. The net removal of dissolved inorganic nitrogen by the tidal marshes (21.1 tonne/year) was a significant fraction of the overall nitrogen budget for the estuary and provided a buffer to potential impacts of point-source wastewater discharges as well as nonpoint urban runoff.

Research was performed on eleven freshwater wetlands and intertidal salt marshes in the Southeast (Nixon, 1986). All of the studies showed that the wetlands acted as sinks for total nitrogen (TN) and phosphorus (TP). Nitrogen fixation ranged from virtually zero up to $40 \text{ g N/m}^2\text{/yr}$, with highest rates generally in salt marshes where it appears that this process may play an important role in the nitrogen budget. Rates of reported measurements of denitrification varied from 2 to $110 \text{ g N/m}^2\text{/yr}$ lost to the atmosphere and confirm the general impression that the removal process is of considerable importance in the nitrogen budget of wetland systems. Some data also suggested that swamps may preferentially remove inorganic, oxidized forms of nitrogen and phosphorus or convert them to reduced, inorganic forms. The other major mechanism by which wetlands serve to remove nutrients is through burial in peat and sediments.

The following assumptions were made from this literature review:

- The major mechanism for exporting particulate organic matter from the marsh to adjacent waters is vegetative decay.
- Dissolved organic matter is exported from the marsh during ebb tides (mainly spring events).
- Dissolved oxygen transported into the marsh by each flood tide is consumed by sediment SOD and never sees the estuary again.
- The forces of deposition on, and retention by, the marsh remain essentially constant. During and after storm periods export by turbulent scour far exceeds mass import back to the marsh by settling and filtering. As the time between storms increases, the effects of turbulent scour diminish and deposition/retention increase, until the marsh and adjacent waters reestablish equilibrium.

Long-term and short-term considerations must be made when developing loadings for the water quality model. In the long term, over a month or a year, nutrient import can dominate export. In the short term, following storms, export dominates. This is especially important when interpreting loading rates from a literature review, where data can range from hourly to annual rates. Caution must be used when extrapolating rates that were measured in the field over a day to equivalent annual rates. Therefore, the Maybank Project results were combined with the Savannah Harbor field data in 1999 with literature rates to estimate the daily loading rates, as described below.

In the Maybank Project report (EPA, 1984), a range of TOC loads exported from marsh areas in South Carolina was given to be 4.01 to 9.25 lb/acre/tidal cycle. These loads were converted to lbs/day by using the tide cycle reoccurring every 12.4 hours. Then, the actual marsh areas were multiplied by the loading rates to produce a TOC in lbs/day. The loads were then converted to ultimate BOD based on a literature conversion (Thoman and Mueller, 1997). Tables X-3a and -3b show the calculations for each the ten Q zones based on this marsh loading range to generate a minimum and maximum load of 144,026 to 322,229 lbs/day, respectively.

A second approach was examined by using the actual LTBO_D results from the 1999 marsh transect data (ATM, 2000). The LTBO_D results from marsh transects 1 and 2 were similar by examining the mid-ebb results minus the mid-flood result at 120 days equal to 1 mg/L (4 – 3 mg/L). The resultant from marsh transects 3 and 4 was 2 mg/L (5 – 3 mg/L). Marsh transect 5 exhibited different characteristics by having a much larger ebbing tide LTBO_D result of 13 mg/L. By subtracting the flood tide result of 4 mg/L, the difference produces a 9 mg/L export of ultimate BOD from the marsh. This result was expected to due marsh transect 5 farther downstream in the estuary and having higher salinities. Generally, higher salinity marshes will produce larger organic loads due to the life cycle of *spartina* vegetation. To develop marsh volumes, the actual marsh areas were multiplied by the actual (average) depths of the each marsh as reported in Table X-1. The flows were calculated by assuming the marsh fills during one-half of the tidal cycle and using the computed volumes. The ultimate BOD load calculated from this approach was 186,915 lbs/day as shown in Table X-4. The calculations are also shown in this table with assumptions noted.

These approaches were used as rough estimates based on field data (Savannah, GA and Maybank, SC) and literature values. The first estimate of the load was used as the middle of the first approach to the calculated load in the second approach (161,624 to 186,915 lbs/day). The ultimate BOD load was input to the WASP model and then adjusted to meet the instream ultimate BOD results nearest to those marsh locations.

Table 7 Marsh BOD Load Calculation Based on Minimum Export Range (EPA, 1984)

input-----> 4.01 = lb/acres/tidal cycle (4.01 to 9.25 based on EPA, 1984)
 7.76 = lb/acres/day (cycle every 12.4 hours)
 2.7 = BODU/TOC (Thomann and Mueller)

Marsh	Actual Area (ac)	TOC (lb/day)	BODU (lb/day)
Q1	490	3,800	10,260
Q2	2,190	16,996	45,888
Q3	1,363	10,580	28,565
Q4	336	2,607	7,040
Q5	210	1,632	4,408
Q7	247	1,918	5,179
Q8	682	5,295	14,295
Q9 ¹	946	7,339	19,814
Q10	409	3,176	8,576
TOTAL =		53,343	144,026

¹ Q6 area is added and included in Q9

Table 8 Marsh BOD Load Calculation Based on Maximum Export Range (EPA, 1984)

input-----> 9.25 = lb/acres/tidal cycle (4.01 to 9.25 based on EPA, 1984)
 17.90 = lb/acres/day (cycle every 12.4 hours)
 2.7 = BODU/TOC (Thomann and Mueller)

Marsh	Actual Area (ac)	TOC (lb/day)	BODU (lb/day)
Q1	490	8,765	23,666
Q2	2,190	39,205	105,852
Q3	1,363	24,404	65,892
Q4	336	6,014	16,239
Q5	210	3,766	10,167
Q7	247	4,425	11,947
Q8	682	12,213	32,976
Q9 ¹	946	16,928	45,706
Q10	409	7,327	19,783
TOTAL =		123,048	332,229

¹ Q6 area is added and included in Q9

Table 9 Marsh BOD Load Calculation Based on 1999 Marsh Transects (ATM, 2000)

ATM Transect 1 & 2 =	1	mg/L BODU	} difference between mid-flood and mid-ebb LTBOD samples at 120 days
ATM Transect 3 & 4 =	2	mg/L BODU	
ATM Transect 5 =	9	mg/L BODU	

Marsh	Actual Area (ac)	Actual Depth (m)	BODU (mg/L)	Flow (cms) ²	BODU (lb/day)
Q1	490	0.12	2	11	4,017
Q2	2,190	0.25	2	98	37,318
Q3	1,363	0.18	9	45	77,434
Q4	336	0.21	2	13	4,877
Q5	210	0.20	2	8	2,876
Q7	247	0.29	9	13	22,230
Q8	682	0.14	1	17	3,301
Q9 ¹	946	0.21	1	37	6,963
Q10	409	0.22	9	16	27,898
TOTAL =					BODU (lb/day) 186,915

¹ Q6 area is added and included in Q9

² to calculate flow = marsh area * marsh depth / 1/2 tidal cycle
this is assuming that the marsh fills over 1/2 the tidal cycle

Other References:

ATM, 2000: Hydrodynamic and Water Quality Monitoring of the Lower Savannah River Estuary, August 2 through October 9, 1999. Engineering report prepared for the Georgia Ports Authority, Savannah, GA.

ATM, 2003: Savannah Harbor Deepening Project, Tidal Marsh Studies Data Report, Volume 1, Volume 3 Marsh Vegetation Data.

Thomann, R.V. and J. A. Mueller, 1997. Principles of Surface Water Quality Modeling, Prentice Hall.

APPENDIX F

Development of Critical Conditions

F.1 States' Requirements for Critical Conditions

In May 2000 and May 2003 letters, Georgia and South Carolina set the critical conditions for Savannah Harbor as:

- Upstream boundary determined by the States' Savannah River Model
- Harbor model kinetic rates and parameters as determined by the Savannah Harbor Model calibration
- 1999 harbor channel bathymetric physical conditions
- Critical flow as equivalent to the 7Q10 flow, taking into account the low flow release from Thurmond Dam
- Meteorological and tidal conditions based on 1999 data
- Dischargers at NPDES limits expressed as monthly averages

For an estuarine TMDL, critical conditions are more complex than the critical conditions typically considered for a river system (e.g., summer temperatures and the 7Q10 flow). Tidal dynamics play an important role in the DO levels of the Savannah Harbor. Therefore, critical conditions applied to the Savannah Harbor DO TMDL are based on model runs in August of 1999 which incorporate the existing harbor physical conditions and the 7Q10 flow as well as actual historic tidal regimes, temperature and other meteorological conditions measured during these periods.

The critical segment of the Savannah Harbor system is defined as the segment of the Harbor with the lowest daily DO average. This segment is a four mile segment around the Savannah Harbor sediment basin (River Mile 9.3 to 14.3).

F.2 Summary of Model Critical Conditions

- Time Period of August 1999
 - Clio USGS gage flows
 - Tidal conditions
 - Meteorological data
- Headwater Natural Conditions
 - August 1999 flows
 - CBODu = 2 mg/l
 - Ammonia = 0.25 mg/l
 - DO = 7 mg/l
- Headwater 1999 Loads based on EPD-RIV1 Output
- Heat Loads to Savannah Harbor
 - Natural Conditions without heat loads
 - Heat Loads included in TMDL run
- Oxygen Demanding Loads

- TMDL loading distributed to the on Front River of the Harbor.

F.3. Clyo USGS Flows

Figure 5 illustrates the 7 day average 1999 flow regime for the Savannah River at the Clyo USGS gage. The August 1999 period include a 7 day average of 6,010 cfs which is equivalent to the June monthly 7Q10 flow of 6008 cfs and slightly less than the August monthly 7Q10 flow of 6,186 cfs. Monthly 7Q10 flows are shown in figure 6.

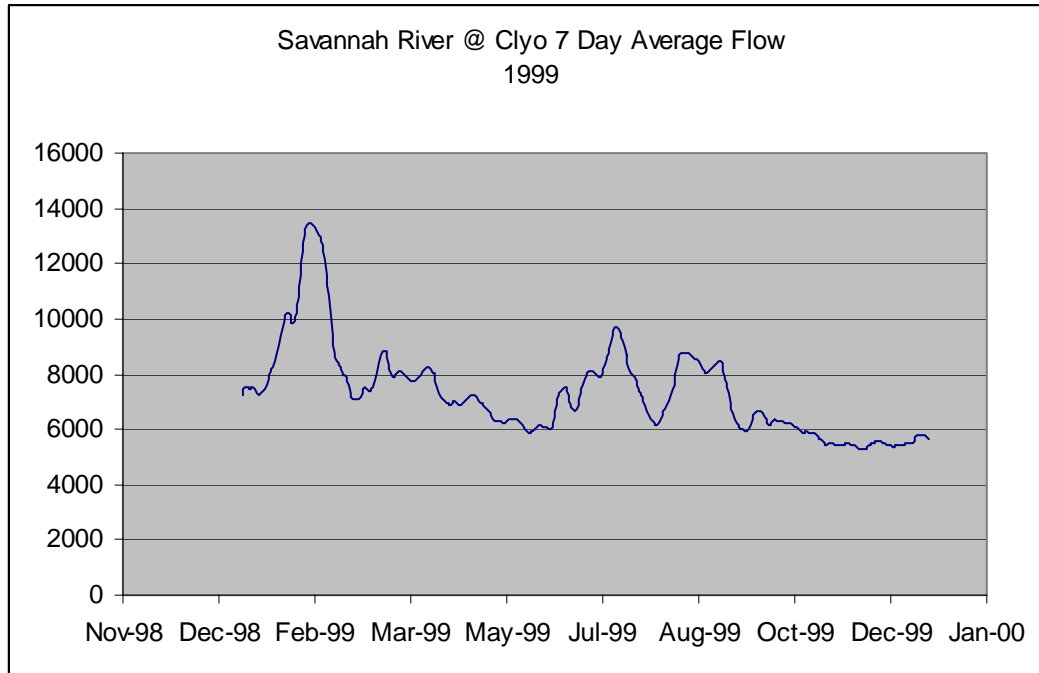


Figure 5 Savannah River @ Clyo 7 Day Average Flow 1999

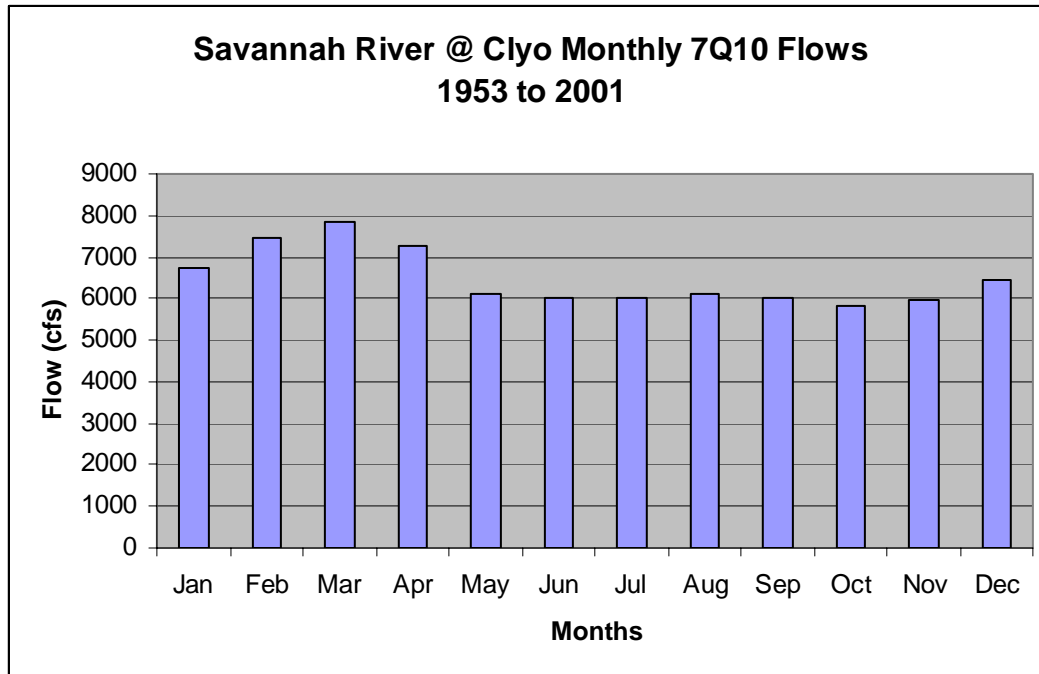


Figure 6 Savannah River at Clyo Monthly 7Q10 Flows 1953 to 2001

F.4 Upstream Oxygen Demanding Substances Loads

The Savannah River EPD-RIV1 dynamic flow and water quality model was used to transport the CBODu and Ammonia loads from the Middle Savannah River Basin (below Thurmond Dam and upstream Clyo USGS gage) to the headwater boundary of the Savannah Harbor model. The river model was run for 5 years, from 1997 to 2001.

The 1999 river model CBODu and Ammonia loads output at Clyo were used in the existing load run for the Harbor model. The output from a 1999 river model run with no point source discharge loads was used to determine natural background loads for the “natural conditions” Harbor model 1999 run.

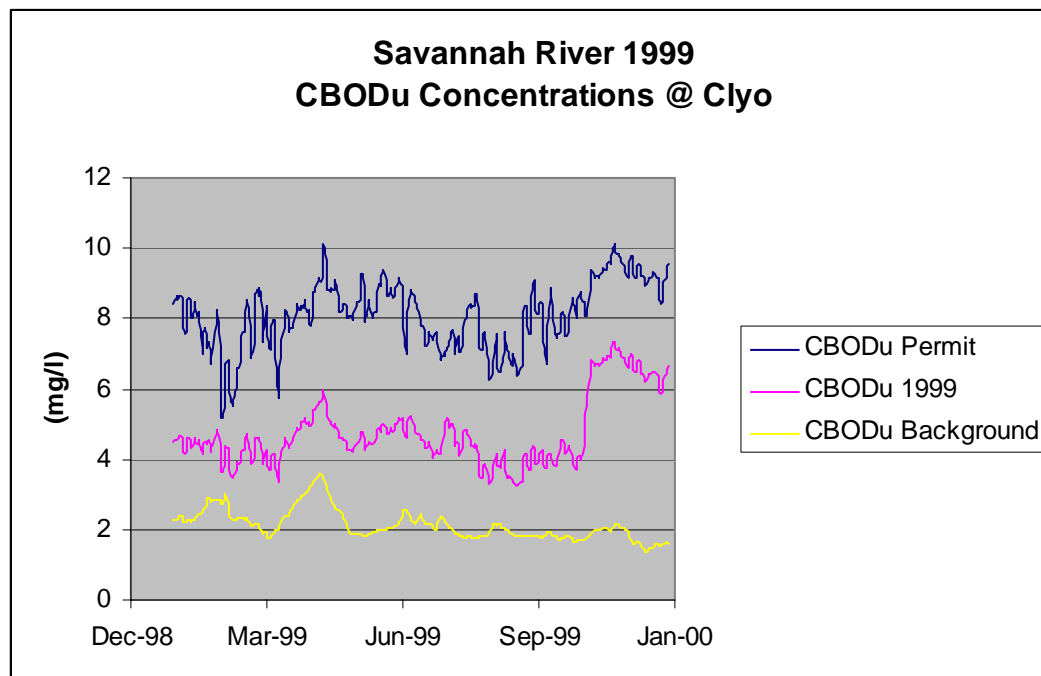


Figure 7 CBODu Concentrations at Clyo

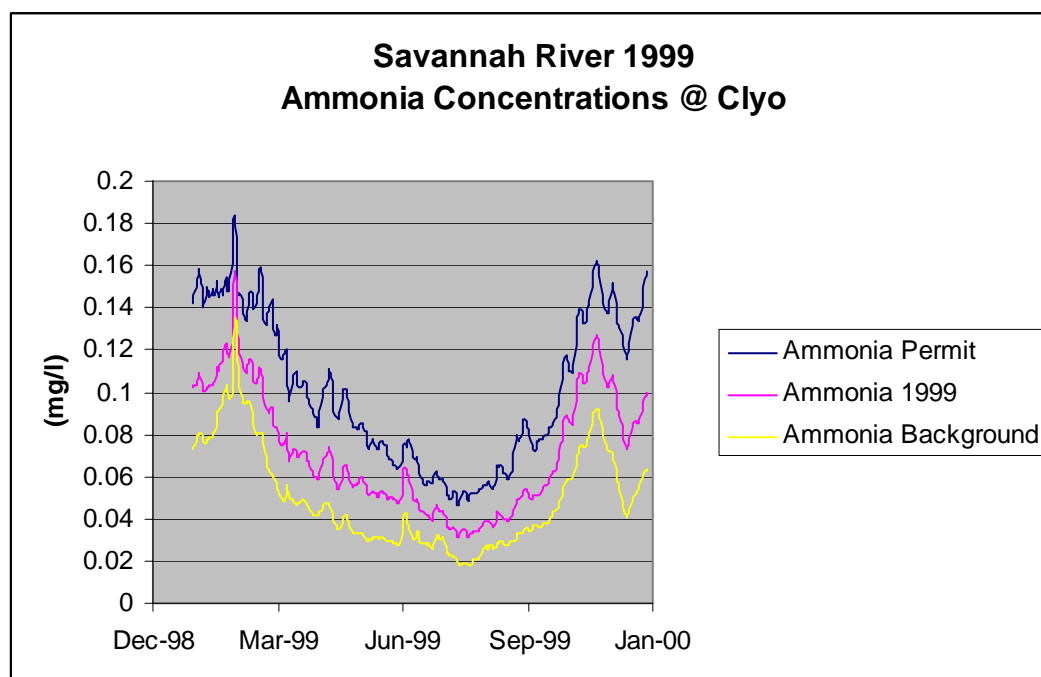


Figure 8 Ammonia Concentrations at Clyo

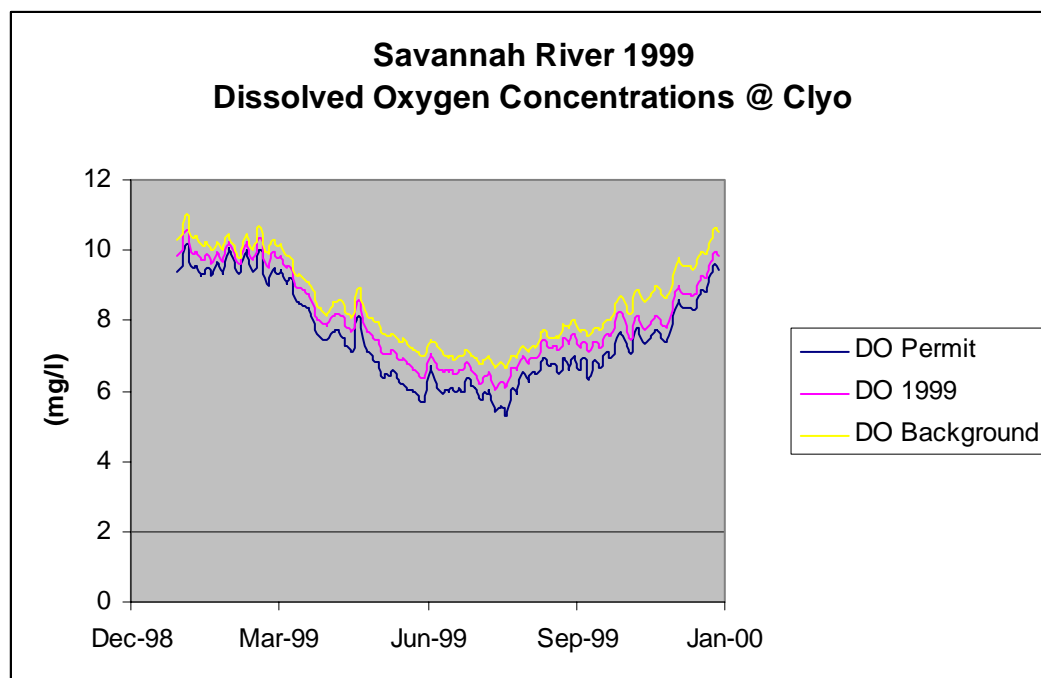


Figure 9 Dissolved Oxygen Concentrations at Clyo

F.5. Example TMDL Scenarios to meet the Suggested DO Criteria

The Savannah Harbor TMDL equals the oxygen demanding substances load (expressed as TBODu) discharging to the Harbor, as well as natural background loads. The TMDL equals:

- WLA of 132,000 lbs/day TBODu from permitted dischargers to meet the a DO deficit of 0.4 mg/l
- LA of 230,000 lbs/day from upstream and marsh natural background contributions and the TBODu impacts from the Ocean.

Three example scenarios are developed to illustrate the possible distribution and range of the distributions of the WLA portion of the TMDL between the upstream and Harbor point sources. Note that the upstream point source loading is expressed as the TBODu loading that is allowable at the Clyo USGS gage. This takes into consideration the decay and resultant removal of the TBODu as it is transported from Clyo to the harbor critical segment but does not consider the decay and removal in the Savannah River.

Example scenario one is the equal division of the DO impact of the point source loads between Harbor and upstream dischargers.

- WLA for the Harbor point sources equals 66,000 lbs/day yielding a 0.2 mg/l DO deficit in the critical Savannah Harbor segment.

- WLA for the upstream point sources equals 66,000 lbs/day yielding a 0.2 mg/l DO deficit in the critical Savannah Harbor segment.

Table 4 – Allocations for the Savannah River and Savannah Harbor

Waterbody	Existing 1999 Discharge Load	Wasteload Allocation	Load Allocation	Margin of Safety	Total TMDL
Savannah River @ Clyo	100,000	66,000	85,000	0	151,000
Savannah Harbor	99,000	66,000	145,000*	0	211,000

* plus Ocean Boundary Conditions of CBODu = 6 mg/l and Ammonia = 0.1 mg/l

Example scenario two is the assignment of all the allowable DO impact to the Harbor point source dischargers.

- WLA for the harbor point sources equals 132,000 lbs/day yielding a 0.2 mg/l DO deficit in the critical Savannah Harbor segment.
- WLA for the upstream point sources equals zero lbs/day yielding a 0.2 mg/l DO deficit in the critical Savannah Harbor segment.

Table 5 – Allocations for the Savannah River and Savannah Harbor

Waterbody	Existing 1999 Load	Wasteload Allocation	Load Allocation	Margin of Safety	Total TMDL
Savannah River @ Clyo	100,000	0	85,000	0	85,000
Savannah Harbor	99,000	132,000	145,000*	0	277,000

* plus Ocean Boundary Conditions of CBODu = 6 mg/l and Ammonia = 0.1 mg/l

Example scenario three is the assignment of all the allowable DO impact to the harbor point source dischargers.

- WLA for the harbor point sources equals zero lbs/day yielding a 0.2 mg/l DO deficit in the critical Savannah Harbor segment.
- WLA for the upstream point sources equals 132,000 lbs/day yielding a 0.2 mg/l DO deficit in the critical Savannah Harbor segment.

Table 6 – Allocations for the Savannah River and Savannah Harbor

Waterbody	Existing 1999 Load	Wasteload Allocation	Load Allocation	Margin of Safety	Total TMDL
Savannah River @ Clyo	100,000	132,000	85,000	0	217,000
Savannah Harbor	99,000	0	145,000*	0	145,000

* plus Ocean Boundary Conditions of CBODu = 6 mg/l and Ammonia = 0.1 mg/l